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UNDERSTANDING LIGHT AND SOUND

PHYSICS WORKSHOP-3

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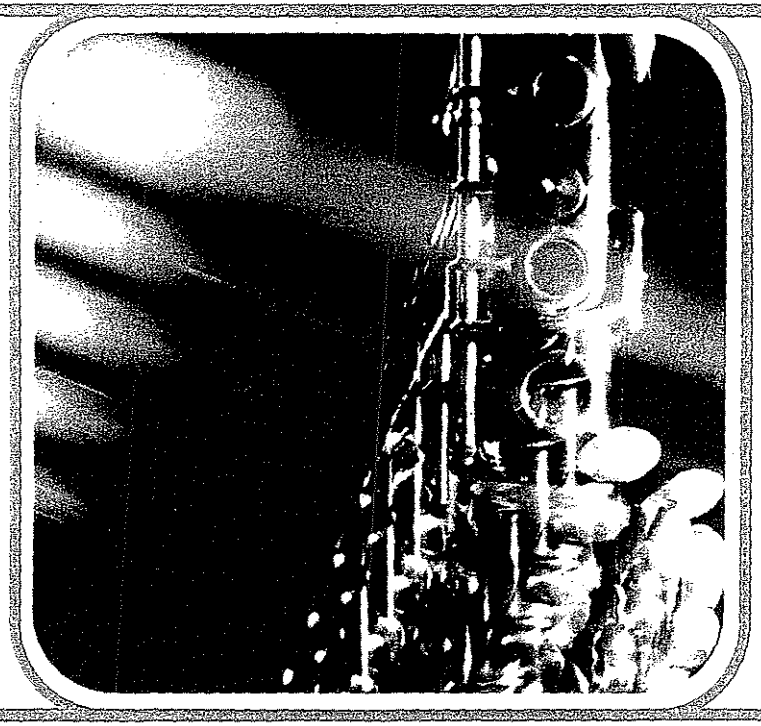

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CONTENTS

What is sound? 1
How does sound travel? 7
How do we hear? 13
How does sound travel through air? 19
What is an echo? 25
What is pitch? 31
How does pitch change? 37
What is resonance? 43
What is loudness? 49
What sounds do columns of air produce? 55
What happens when sounds combine? 61
What are overtones? 69

What are the differences between noise and music? 75

How is light different from sound? 79

What happens to light when it strikes matter? 85

Where does light come from? 91

How does light reflect? 95

What is a shadow? 101

What is refraction? 107

What is a lens? 115

How do we see? 121

How do eyeglasses help some people to see better? 127

What is the visible spectrum? 133

What is invisible light? 137

What gives an object its color? 143

What is laser light? 149

Keeping Up With Science

Stereo: A Good Round Sound 18
The Case of the Speeding House 100
Light Conversation 142

BEFORE YOU BEGIN . . .

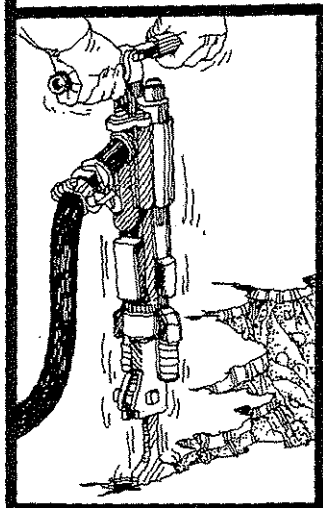
You hear the soft rustling of leaves under your feet. A jet roars overhead. You see the tiniest detail of a rose. Bright spotlights turn the night into day. *Hearing and seeing.* Our ears let us hear everything from sighs to symphonies. Our eyes can recognize over a million colors.

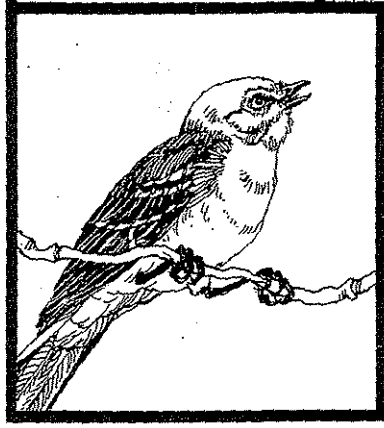
Sound and light are what you will learn about in this book. You will learn why music can be a pleasant sound—and why noise is an *unpleasant* sound. You will also learn about the future uses of laser beams.

Physics Workshop 3 is divided into 26 Aims. Each Aim starts with the information you'll need to know. This is followed by a series of exercises. Take your time on these. Look back to the beginning of the Aim whenever you're not sure of an answer. You'll find experiments and word games to do in the Aims, too.

WHAT IS SOUND?

1





sound: a form of energy

vibrate: to move back and forth very rapidly

molecule: a small part of matter

AIM 1 | What is sound?

All learning is done through our senses. We see, we smell. We feel, we taste. We also hear! We hear *sounds* — all sorts of sounds. We hear words, whistles, squeaks, thumps, music, and many more sounds. Sounds are all around us.

What causes sound? Every sound is caused by vibrating matter. To vibrate means "to move back and forth very rapidly." A guitar string vibrates when it is plucked. Vibrating air molecules make the wind "whistle." Your vocal cords vibrate when you speak. You hit a piece of wood with a hammer, and molecules of both the wood *and* hammer vibrate.

Now you know what causes sound. But what is sound? Do you remember what energy is? Energy is the ability to make something move. Figures E and F show that sound can make something move. SOUND IS A FORM OF ENERGY.

Some sounds, like the chirping of birds and the rustling of leaves, are *pleasant* sounds. They are nice to hear. Other sounds, like chalk screeching on the blackboard and a horn blasting, are *unpleasant* sounds. They are not nice to hear.

Certain sounds that are pleasant to some people are unpleasant to others. Some people, for example, like soft, classical music. Others like loud rock music. It's a matter of taste. But no matter what kind of sound we are talking about, remember:

- There can be no sound without vibration.
- Whenever there is sound, matter is vibrating.

MAKING SOUNDS

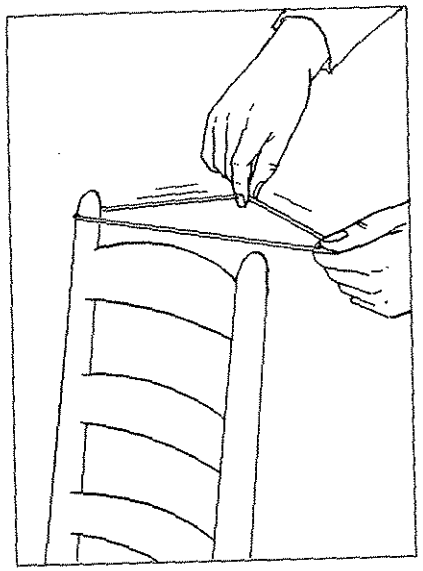


Figure A

Figure B

sounds.

Stretch a rubber band around a faucet or chairpost.

Pluck it.

1. Do you hear a sound? _____
2. a) Do you see the rubber band moving? _____
   b) Is it moving slowly or rapidly? _____
   c) What do we call this kind of movement? _____
3. What is causing the sound here? _____
4. What causes *any* sound? _____

Tear off a small piece of paper.

Hold the edge between your lips. Pull it tightly.

Blow hard.

5. a) Do you hear a sound? _____
   b) What is causing the sound? _____

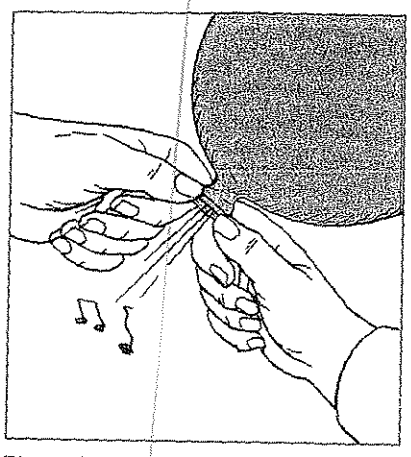


Figure C

Blow up a balloon as large as you can. Do not tie it.

Hold the open end tightly. Stretch the neck of the balloon as in Figure C.

Let the air out slowly.

6. What do you hear? _____

7. Two things are vibrating here. What are they? _____

_____

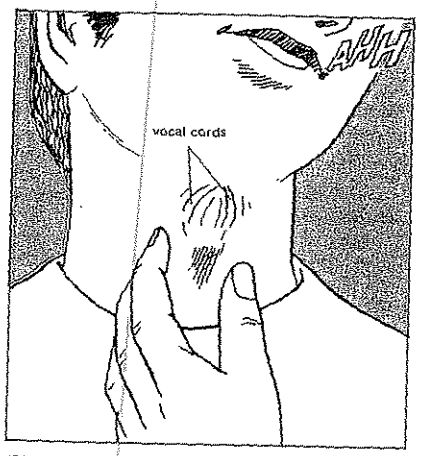


Figure D

Place two fingers *lightly* on your neck as Figure D shows.

Speak.

8. Do you feel vibrations? _____

9. What is vibrating?

_____

10. a) Do dogs and cats have vocal cords? _____

b) How do you know? _____

_____

FILL IN THE BLANKS (One word for each blank.)

1. Sound is caused by _____.
2. There can be no _____ without vibration.
3. If you hear a sound, then you know that something is _____.

SOLVE THIS!

Strike a tuning fork with a rubber hammer.

The tuning fork is vibrating.

1. How do you know? _____

Hold the vibrating fork close to a lightweight plastic ball hanging on a string.

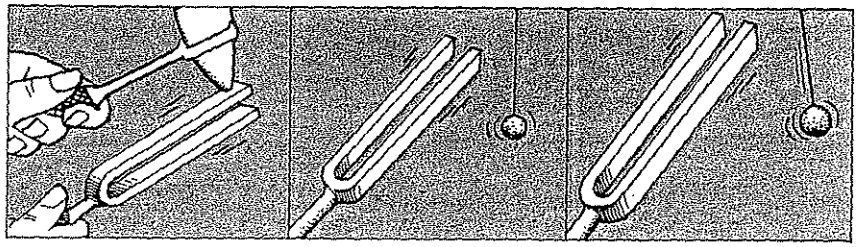


Figure E

The tuning fork is not touching the ball. Yet, the ball is moving.

2. How can you explain this? _____

WHAT IS HAPPENING?

Look at Figure F.

Write a short, short story explaining what is happening.

_____

_____

_____

_____

Figure F

TRUE OR FALSE Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. _____ We learn only by seeing.
2. _____ We learn through all our senses.
3. _____ Hearing is one of our senses.
4. _____ We need light to hear.
5. _____ Hearing depends upon sound.
6. _____ Sound is caused by vibrating matter.
7. _____ Vibrating matter moves back and forth slowly.
8. _____ Our vocal cords are always vibrating.
9. _____ Vibrations can move from place to place.
10. _____ Everyone likes the same sounds.

REACHING OUT

You shake your hand back and forth quickly—and you do not hear a sound. Yet, you can hear the wings of a tiny mosquito buzzing.

1. Why don't you hear the hand movements? _____
2. Why do you hear the mosquito buzzing? _____

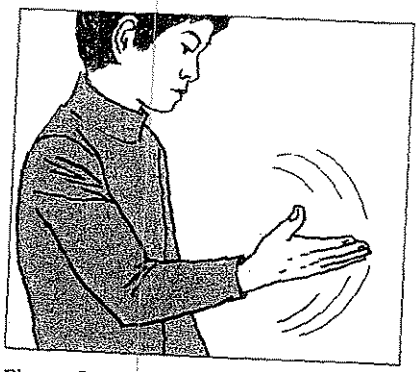


Figure G

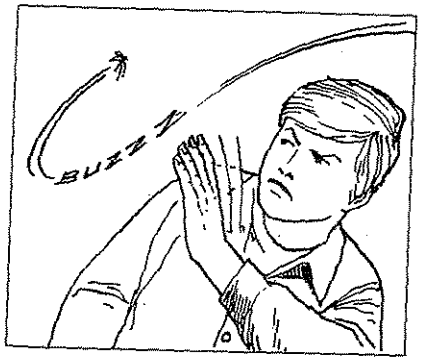


Figure H

HOW DOES SOUND TRAVEL?

AIM 2 How does sound travel?

A friend calls to you. He is across the street. Yet you hear him clearly. His voice is traveling through the air to your ears.

If you and your friend were on the moon, you could not hear him—even if he shouted. The moon has no air to carry his voice vibrations.

Sound moves from place to place but *only* where there is matter. Matter is made up of atoms and molecules. Molecules (or atoms) are needed for sound to travel. The vibrations are passed on from molecule to molecule.

A substance through which sound travels is called a *medium* of sound. *Solids, liquids,* and *gases* are the mediums of sound.

Sound travels at different speeds through different mediums. The speed depends upon how closely packed the molecules are.

The more closely packed, the *faster* the speed of sound.

The more loosely packed, the *slower* the speed of sound.

- The molecules of *solids* are the most *tightly* packed. Sound, therefore, travels *fastest* through solids.
- The molecules of *gases* are the most *loosely* packed. Sound, therefore, travels *slowest* through gases.
- The molecules of liquids are spaced neither very close nor very far apart. Sound, therefore, travels at an in-between speed through liquids.

The ability to make things move is called *energy*. Sound is a form of energy because it makes matter vibrate.

Sound vibrations move in all directions. The vibrations cause *waves*. A wave is like a disturbance. Think of a rock being thrown in water. The rock hits the water. The water makes ripples that move outward. Sound waves move in the same way.

You will learn more about sound waves in Aim 4.

SOUND SPEED IN DIFFERENT MEDIUMS

Look at Figures A, B, and C. Each stands for a different medium of sound. The dots are the molecules.

Study the figures. Answer the questions by figure letters.

1. The molecules are spaced closest in _____ (A, B, C).
2. The molecules are spaced farthest apart in _____ (A, B, C).
3. The molecules are spaced neither very tightly nor very loosely in _____ (A, B, C).
4. Which is the solid? _____ (A, B, C)
5. Which is the liquid? _____ (A, B, C)
6. Which is the gas? _____ (A, B, C)

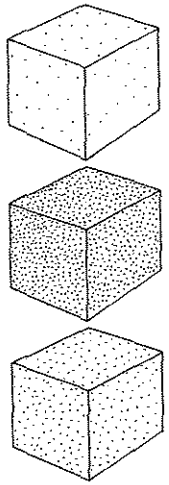


Figure A

Figure B

Figure C

Before you answer the remaining questions about sound mediums, look at Figure D.

7. a) Which row of dominoes will fall first? _____
   b) Why? _____
8. a) Which row will fall last? _____
   b) Why? _____

Now let's get back to the sound mediums.

9. a) Sound will travel fastest through _____ (solids, liquids, gases)
   b) Why? _____
10. a) Sound will travel slowest through _____ (solids, liquids, gases)
    b) Why? _____

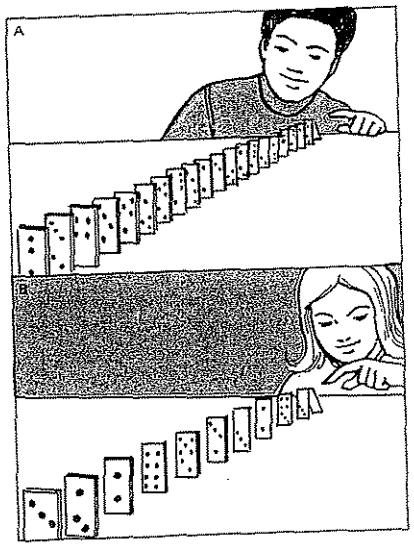


Figure D

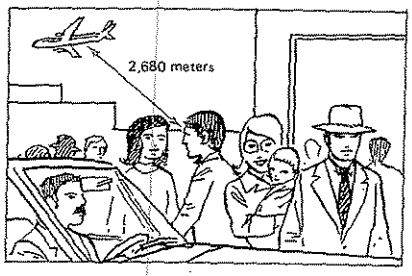


Figure E

How fast does sound travel through air? It travels about 335 meters (1,100 feet) per second.

11. How long will it take the sound of the airplane to reach the people?

_____

How fast does sound travel through water? Sound travels about 1,500 meters (4,900 feet) per second.

In Figure F, the divers on the left are chopping away coral.

12. How long will it take for the chopping sounds to reach the divers on the right?

_____

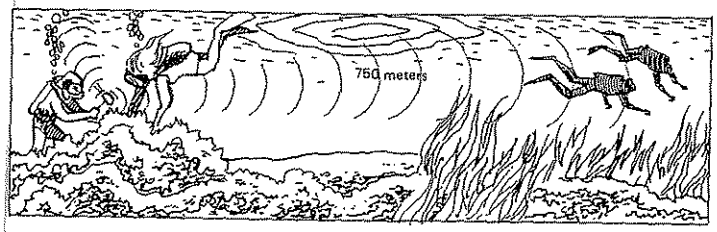


Figure F

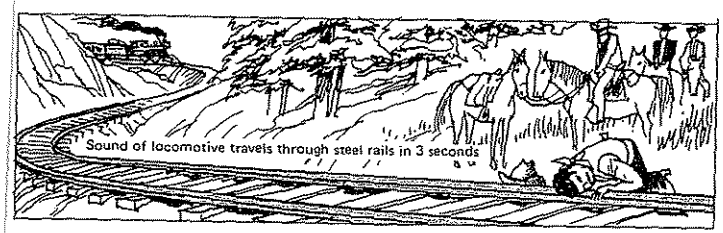


Figure G

How fast does sound travel through solids? It depends upon the solid. For example:

- Sound travels through glass at a speed of 3,720 meters (12,200 feet) per second.
- Sound travels through steel at a speed of 5,200 meters (17,060 feet) per second.

13. How far away is the locomotive in Figure G?

_____ meters _____ feet

TEST YOUR UNDERSTANDING

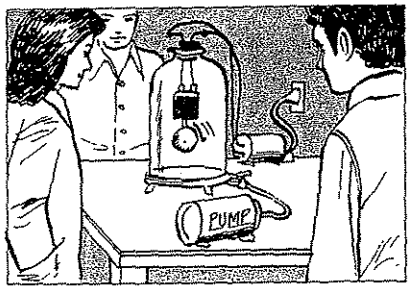


Figure H

Look at Figure H. Then answer the questions.

There is air in this jar. However, the pump is removing the air.

1. a) As the air is removed, the sound becomes _____ (softer, louder).

   b) Why? _____

2. How will you know when just about all the air has been removed? _____

3. Sound needs two things: *vibrations* and a *medium*. Which of these is being removed here? The _____.

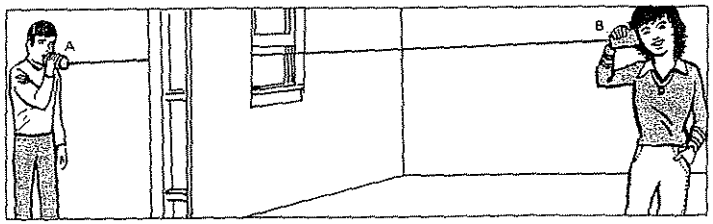


Figure I

Figure I shows a string telephone. You can make one yourself. All you need are two paper cups and about 9 meters (30 feet) of thin string.

The following sentences explain how the string telephone works. But they are not in proper order. Rewrite the sentences in proper order on lines 4–8.

The cord vibrates.
The boy's vocal cords vibrate.
The air in cup B vibrates.
The vibrations go into the girl's ear.
The air in cup A vibrates.

4. _____
5. _____
6. _____
7. _____
8. _____

COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

medium	liquid	gases
move	solids	molecules
gas	vibrations	solid
atoms	directions	

1. Sound is caused by _____.
2. Sound travels through matter. Any matter through which sound travels is called a _____ of sound.
3. All matter is made up of _____ and _____.
4. Matter is any _____, _____, or _____.
5. Molecules are most tightly packed in _____.
6. Molecules are spaced farthest apart in _____.
7. Sound travels fastest through _____.
8. Sound travels slowest through _____.
9. Sound is a form of energy because it can make matter _____.
10. Sound waves move out in all _____.

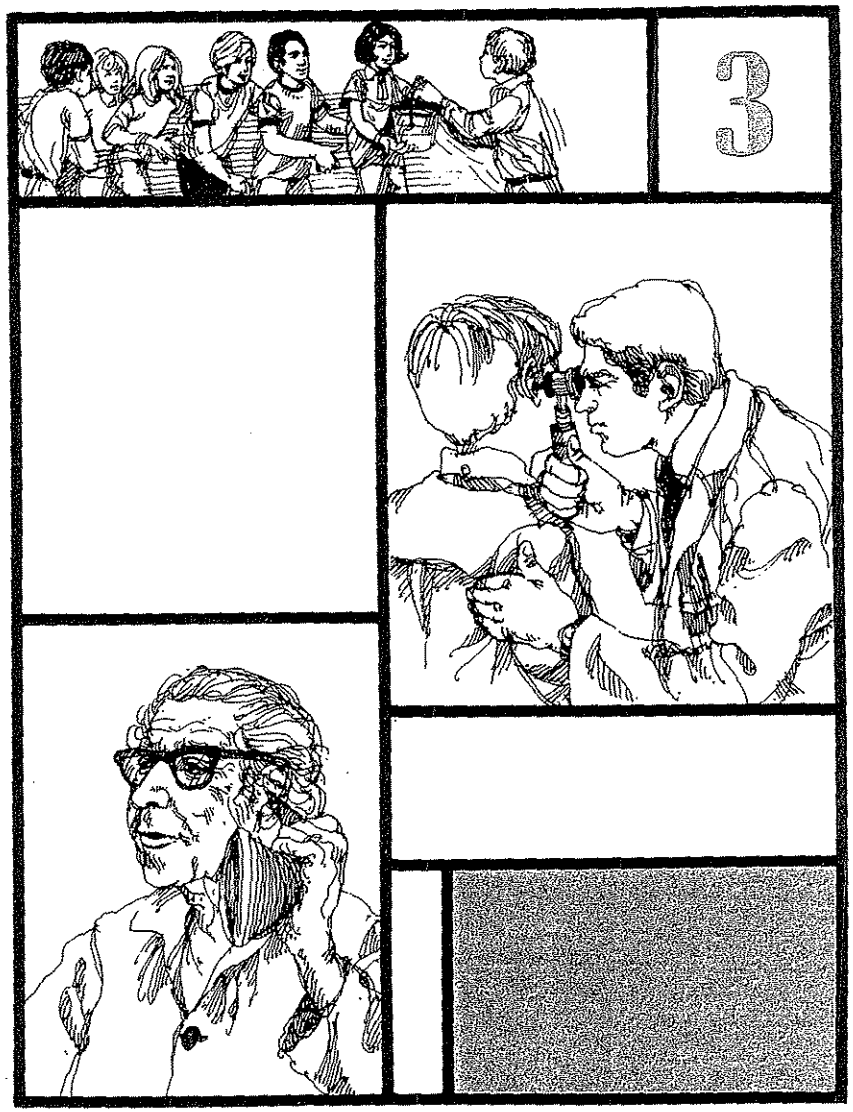
REACHING OUT

Sound waves reach out in all directions. They travel in straight lines. But sound waves can also turn corners. How do you know this is true? _____

_____

_____

HOW DO WE HEAR?



AIM 3 | How do we hear?

Everyone knows that we hear with our ears. But do we? No, not really! We hear with our *brains*. Our ears just pass on vibrations from the air to the brain. The brain then *translates* these vibrations. It decides what the vibrations mean.

WHAT ARE THE PARTS OF THE EAR? The ear is made up of three sections: the *outer ear*, the *middle ear*, and the *inner ear*.

- The *outer ear* has two main parts: the *auricle* [OR i kul] and the *ear canal*.

The *auricle* is the part of the ear that sticks out from the side of the head.

The *ear canal* is a short tube that leads into the head.

- The *middle ear* contains a thin skin-like tissue called the *eardrum*.

The middle ear also contains three tiny bones: the *malleus* [MAL ee us], the *incus*, and the *stapes* [STAY peez].

The ear bones are the smallest bones of the body.

- The *inner ear* contains the *cochlea* [KOK lee uh] and the *semicircular canals*.

The semicircular canals are not for hearing. They help us to keep our balance.

HOW DO WE HEAR? Hearing depends upon vibrations passing from one part of the ear to another. The message of sound must then pass into the brain. The exercise on the following pages traces this path.

HOW SOUND IS HEARD

Figure A shows the inside of the ear. The explanation traces sound vibrations step by step from outside of the ear to the brain. Read the explanations. Find the parts of the ear as you read. Label them on the proper lines.

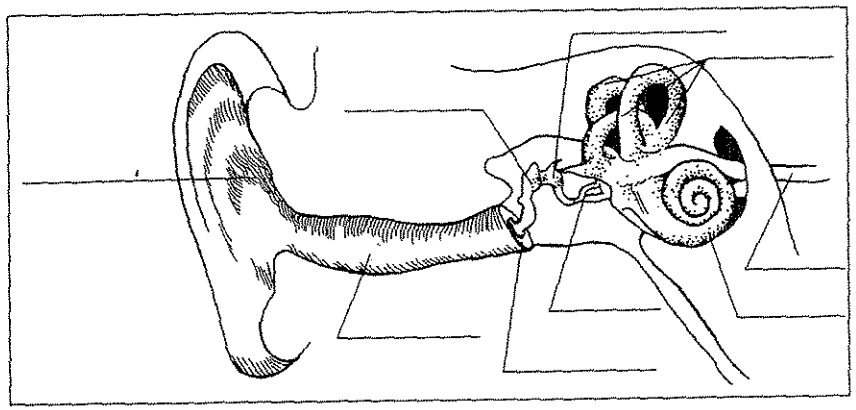


Figure A

1. Sound vibrations are "caught" by the *auricle*.

   Label the auricle.

2. The vibrations then move through the *ear canal*.

   Label the *ear canal*.

3. The vibrations hit against the *eardrum*. The eardrum vibrates.

   Label the *eardrum*.

4. The *malleus* bone is connected to the inside wall of the eardrum. The vibrating eardrum makes the *malleus* vibrate.

   Label the *malleus*.

5. The malleus passes on the vibrations to the *incus* bone.

   Label the *incus*.

6. The incus passes on the vibrations to the *stapes* bone.

   Label the *stapes*.

7. The stapes passes on the vibrations to the *cochlea*.

   Label the *cochlea*. (It is shaped like a snail.)

8. The cochlea is filled with a liquid. The inside wall is lined with tiny hairs. The vibrations move the fluid and the hairs. This sets up a sensation in the nerves that are connected to the cochlea. The nerves become a single nerve called the *auditory nerve*.

   a) Label the *auditory nerve*.

   b) Where does the auditory nerve end up? _____

9. The *semicircular canals* are part of the inner ear. But they have nothing to do with hearing.

   a) Label the semicircular canals.

   b) What do the semicircular canals do? _____

_____

COMPLETING SENTENCES

Complete the sentences with the choices below.

middle ear	auricle	hairs
three	ear	outer ear
malleus	eardrum	inner ear
auditory nerve	ear canal	fluid
brain		

1. The organ of hearing is the _____.
2. Hearing actually takes place in the _____.
3. The ear is divided into _____ sections.
4. The sections of the ear are the _____, the _____, and the _____.
5. The part of the outer ear that gathers sound vibrations is called the _____.
6. The tube that leads from the auricle is called the _____.
7. The part of the ear that vibrates *first* is called the _____.
8. The ear bone that vibrates first is called the _____.
9. The cochlea is lined with tiny _____ and filled with a _____.
10. The nerve that sends sound messages to the brain is called the _____.

IDENTIFYING THE PARTS OF THE EAR

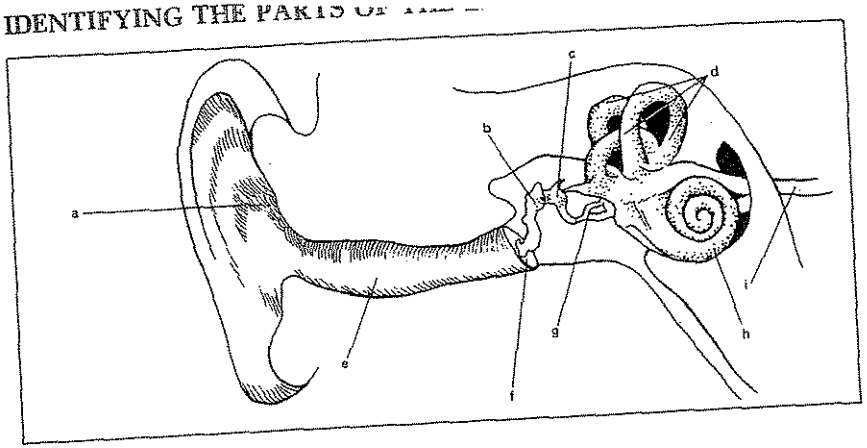
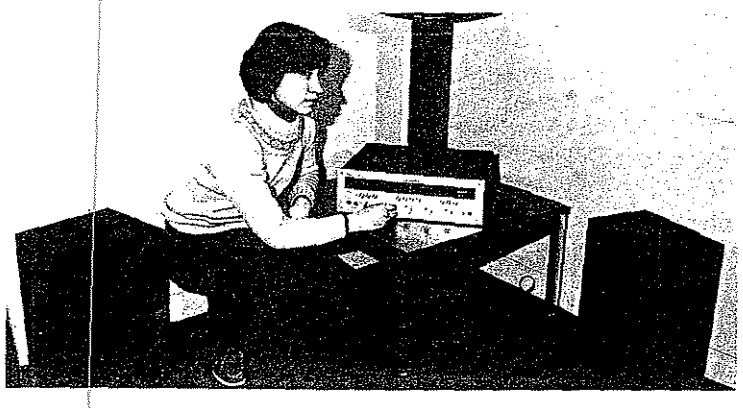


Figure B

Identify the parts of the ear by letter.

1. _____ cochlea
2. _____ ear canal
3. _____ incus
4. _____ auditory nerve
5. _____ auricle
6. _____ semicircular canals
7. _____ stapes
8. _____ eardrum
9. _____ malleus
10. Which of these are bones? _____
11. List the parts of the outer ear. _____
12. List the parts of the middle ear. _____
13. List the parts of the inner ear. _____
14. Which part of the inner ear deals with hearing? _____
15. Which part of the inner ear deals with balance? _____

HIGH FIDELITY WITH SCIENCE



STEREO — A GOOD ROUND SOUND

Everyone likes music. But not everyone likes the same kind of music. Which kind do you like? Popular, Rock, Country, Western—or perhaps classical?

We may not agree which kind of music is best, but everyone agrees that any kind of music sounds better played in *stereo*.

Stereo uses two speakers spaced several feet apart. Each speaker sends out a different kind of sound. For example, the left speaker may deliver only the high notes, and the right speaker only the base notes. Together they fill the air with enjoyable "rounded" sound. The same music played in *mono* (one-speaker system) sounds flat by comparison.

Why do we prefer stereo music over mono music? Many experts think that we have "developed an ear" for stereo sound. They claim this had come about since the development of high-fidelity stereo equipment. Dr. M.R. Schroder, disagrees.

Dr. Schroder, who works at Bell Laboratories in New Jersey, has been studying this question. He claims that stereo sound stimulates the hearing section of the brain more than mono sound does. He believes the larger the brain area that is stimulated, the greater is the enjoyment.

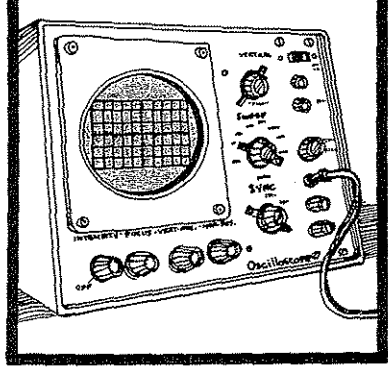
Controlled experiments seem to confirm Dr. Schroder's theory. In fact, his studies indicate that people get most pleasure when the sound reaching each ear is as different as possible—at the same spot of the recording.

Opposite studies involving *similar* sounds were also done. Enjoyment was reduced. Probably a smaller area was stimulated.

Dr. Schroder's findings are impressive. However, they are still theory and based only on a few studies. Further studies are needed to make his theory a scientific fact.

HOW DOES SOUND TRAVEL THROUGH AIR?

4



crest: a high point

trough: a low point

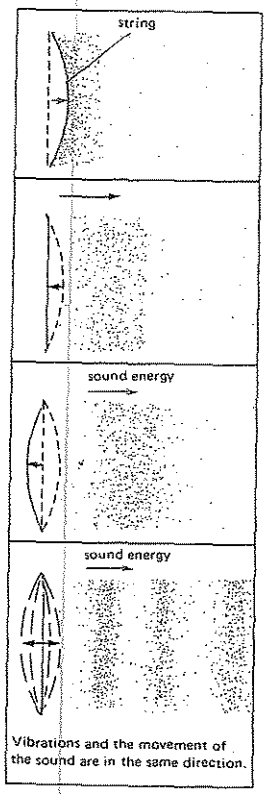
oscilloscope: an instrument that shows wave patterns

longitudinal wave: a wave that moves in the same direction as its length

AIM 4 How does sound travel through air?

Every vibration produces a *sound wave*. A sound wave travels through the air in a special way.

You cannot see air molecules. But imagine that you could. What would you see? What does a sound wave do to the molecules? Look at the diagrams and explanations on this page. The dots stand for air molecules.



Vibrations and the movement of the sound are in the same direction.

1. An object, like a guitar string, is plucked. It vibrates.

   First the string moves to one side. It pushes the air molecules in front of it. The molecules crowd together. They become *compressed* [kum PREST].

2. The compressed molecules move forward. They move *away* from the vibration that started them moving. The string moves back to a "neutral" position.

3. The string now swings to the *opposite* direction. The molecules become *less* crowded. They are more spread out. We say the air becomes *rarefied* [RARE uh fide].

4. The string keeps vibrating back and forth. The air becomes compressed and rarefied over and over again. Soon the air becomes filled with waves of compressed and rarefied molecules. We call these waves *longitudinal* [lon ji TOOD uh nul] *waves*. Sound waves are longitudinal waves. A longitudinal wave vibrates in the same direction as its length.

UNDERSTANDING SOUND WAVES

You cannot see a sound wave. But you *can* see light. Sound is a form of energy. And energy can change from one form to another.

An instrument called an *oscilloscope* [uh SILL uh SKOPE] changes sound to *electrical* energy. Then the electrical energy changes to *light* energy. The light energy shows the pattern of the sound wave.

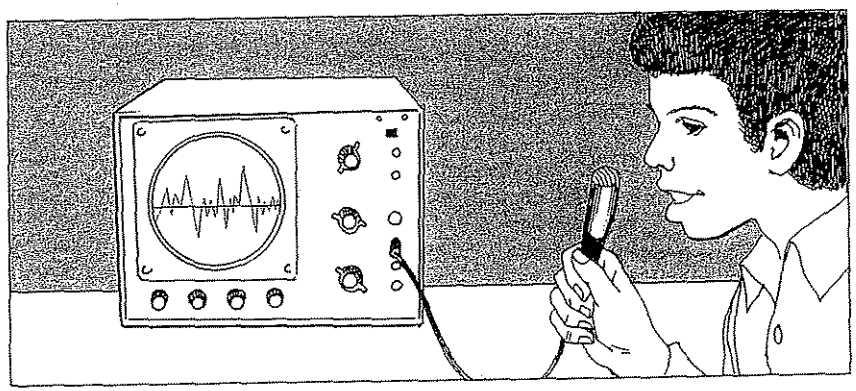
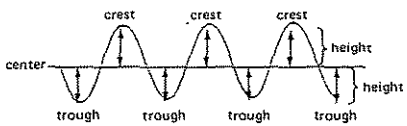


Figure A

Every sound has its own special wave pattern. This is the wave pattern of one kind of sound.

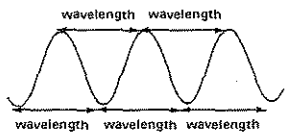
A sound wave has a *high* point and a *low* point.

- The high point is called the *crest*.
- The low point is called the *trough* [TRAWF].



The distance from the center of a wave to either its high or low point is called its *height*.

A wave also has *length*. The length of a wave is called its *wavelength*.



A wavelength is the distance between the crests or troughs of two waves that are next to each other.

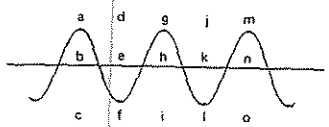


Figure B

Now name the parts of a wave.

Figure B shows a sound wave. It is labeled with letters a through o. Which part of a sound wave do these letters show? Choose from these terms:

crest	trough
wave height	wavelength

Write the correct term in the blanks.

1. a _____
2. l _____
3. gh _____
4. fl _____
5. ab _____
6. ag _____
7. gm _____
8. kl _____
9. mn _____
10. m _____
11. ef _____
12. f _____

MEASURING WAVES

Four sets of waves are shown in Figures C through F. Measure the height and length of each with your metric ruler. Write the measurements in the spaces under each set of waves.

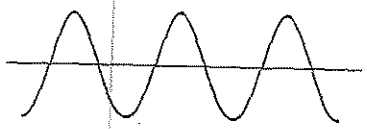


Figure C

1. wavelength _____ mm
2. wave height _____ mm

Figure D

3. wavelength _____ mm
4. wave height _____ mm

Figure E

5. wavelength _____ mm
6. wave height _____ mm

Figure F

7. wavelength _____ mm
8. wave height _____ mm

HOW A LONGITUDINAL WAVE MOVES

A Slinky toy can give you an idea how a longitudinal wave moves.

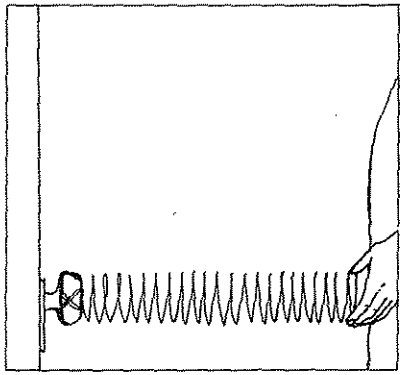


Figure G

1. Tie one end of the Slinky to a doorknob. Stretch it out about 1½ meters (5 feet).

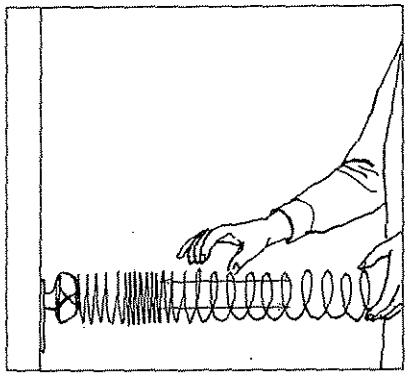


Figure H

2. Pluck the Slinky. This compresses—then releases—energy. Notice that the energy moves *forward*. It moves *in the direction of its length*, just like a longitudinal wave.

   What happens to the energy when it reaches the end of the Slinky?

   _____

   A longitudinal wave acts this way too!

COMPLETING SENTENCES

Complete the sentences with the choices below.

sounds	compressed	trough
wavelength	waves	height
energy	longitudinal	oscilloscope
rarefied	crest	

1. Sound is a form of _____.
2. Sound energy moves through the air in _____.
3. Sound waves are _____ waves.
4. When a sound wave moves through air,
   a) first the air molecules are crowded together. They are _____.
   b) then the molecules move apart. They are _____.
5. We can "see" a sound wave with an _____.
6. The *high* point of a wave is called its _____.
7. The *low* point of a wave is called its _____.
8. The distance between the center of a wave and either its crest or its trough is called its _____.
9. The distance between two crests or two troughs is called a _____.
10. Different _____ have different wave patterns.

REACHING OUT

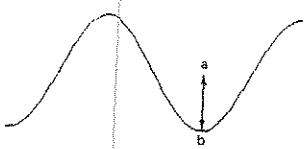


Figure I

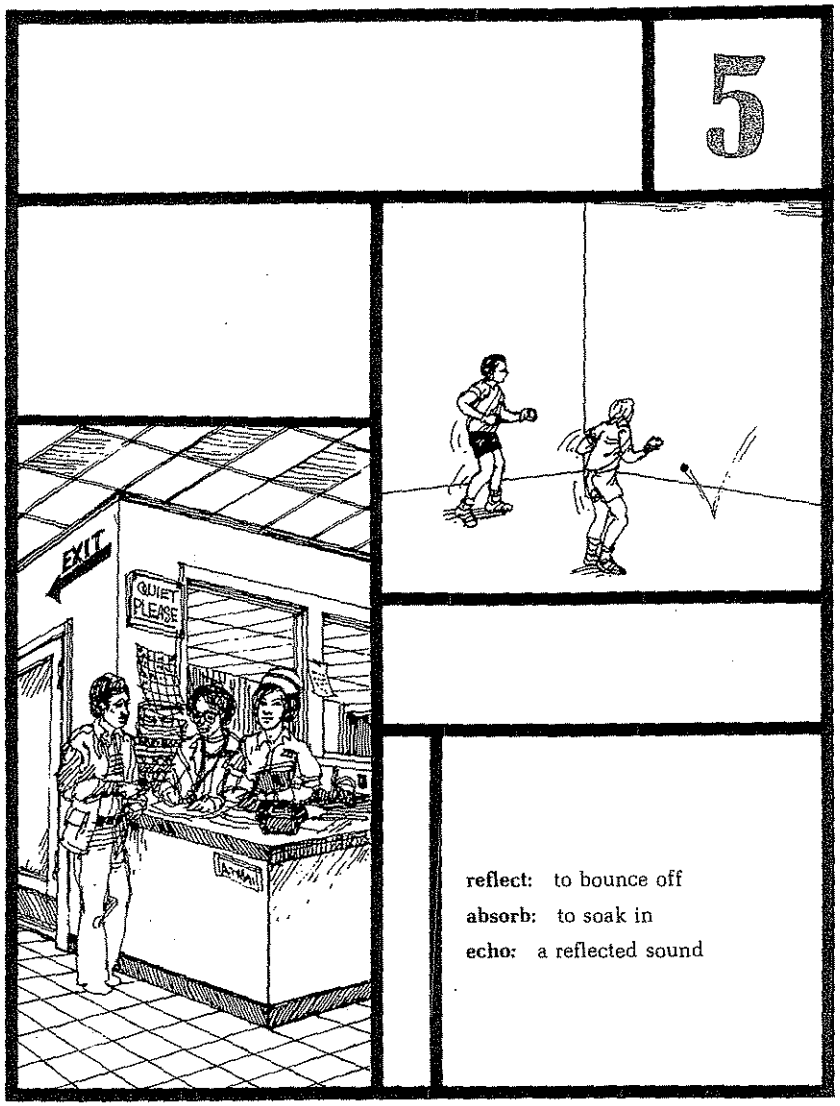
Every wave has a *compressed* part and a *rarefied* part.

In Figure I, ab stands for the compressed part.

Which part stands for the *rarefied* part?

Draw a line where you think it is. Label it cd.

WHAT IS AN ECHO?



reflect: to bounce off
absorb: to soak in
echo: a reflected sound

AIM 5 What is an echo?

You throw a rubber ball against a brick wall or sidewalk and it bounces back. Sound bounces, too. A sound that bounces off a surface is called an *echo*.

Did you ever hear an echo? You can produce one easily. Just stand at least 17 meters (55 feet) from a brick wall. Then clap your hands. Almost immediately you hear the echo of the clap. You can do the same with your voice. Cup your hands and shout in the direction of the wall. You will hear your voice "talking back" to you.

Sound, like a ball, does not bounce off all surfaces.

A ball will bounce easily from a hard surface, like brick, concrete, or wood. But a ball hardly bounces off soft surfaces, like loose sand or mud.

Sound acts in the same way. Sound will bounce, or *reflect*, off hard surfaces but not off soft surfaces. Sound that bounces off a hard surface produces an echo. Sound that hits a soft surface is *absorbed*.

It is important that some places be as quiet as possible. Heavy carpets, curtains, and soundproofing tiles help reduce the amount of sound. They prevent echoes and absorb sound in general.

UNDERSTANDING ECHOES

Look at Figures A through D. Then answer the questions with each.

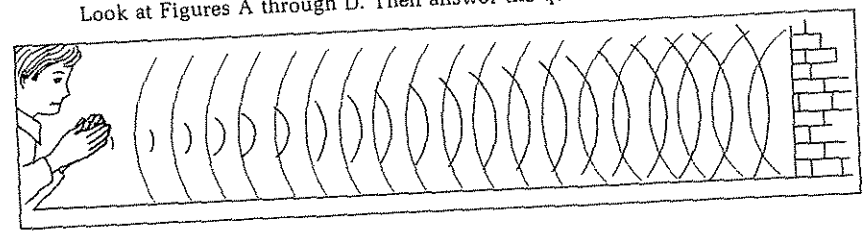


Figure A

The boy in Figure A is clapping his hands. The sound bounces off the wall. An echo is produced.

1. Draw two arrows on Figure A to show the path of the sound waves.
2. The wall is made of _____ (soft, hard) material.
3. Name three materials this wall may be made of: _____
4. You want to "kill" the echo. With what might you cover the wall? _____
5. Sound that produces an echo is _____ (absorbed, reflected).

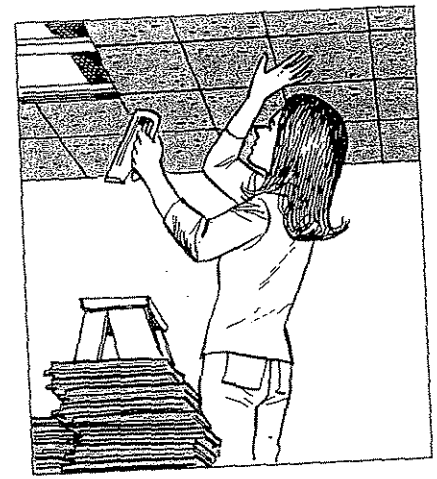


Figure B

6. Sound that is "taken in" is _____ (absorbed, reflected).
7. Hard materials _____ (absorb, reflect) sound.
8. Soft materials _____ (absorb, reflect) sound.

The person in Figure B is putting up soundproofing ceiling tiles.

The tile material absorbs sound. The design also helps.

9. What design feature helps absorb sound? _____

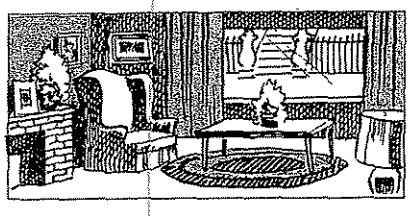


Figure C

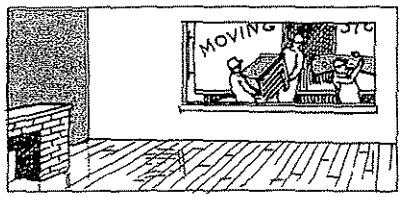


Figure D

10. a) The room in Figure _____ is probably noisier than the
C. D

room in Figure _____.
C. D

b) Why? _____

_____

11. a) Will the noisy room always be noisy? _____

b) When will it be quieter? _____

COMPLETING SENTENCES

Complete the sentences with the choices below.

an echo	hard	fabric
concrete	"soak in"	sound
foam rubber	wood	soundproofing
"bounce back"	absorb	soft

1. *Absorb* means _____.
2. *Reflect* means _____.
3. _____ can be absorbed or reflected.
4. Reflected sound can produce _____.
5. Sound reflects best off _____ surfaces.
6. Sound is absorbed by _____ surfaces.
7. Two materials that absorb sound are _____ and _____.
8. Two materials that reflect sound are _____ and _____.
9. Materials that reduce noise are called _____ materials.
10. Soundproofing materials _____ sound.
one word

ABSORBS OR REFLECTS?

Eight materials are listed below. Each one either *absorbs sound* or *reflects sound*. Which does each do?

Write your answer in the proper boxes.

	Material	Absorbs sound or reflects sound?
1.	wood	
2.	cork	
3.	bathroom tile	
4.	concrete	
5.	brick	
6.	foam rubber	
7.	fabric	
8.	plastic (like table tops)	

SOMETHING INTERESTING

Have you taken any photographs lately?

Reflected sound is now used to focus some cameras. Read the explanation and look at Figure E to find out how.

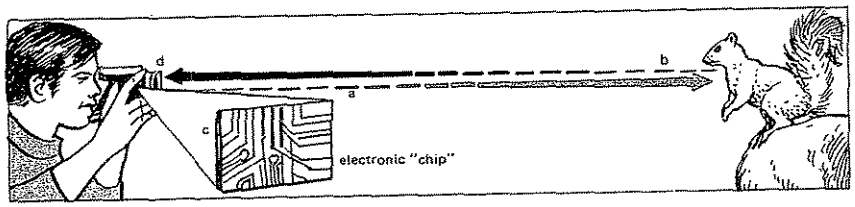


Figure E

a. The camera sends out a very short-wave sound. You cannot hear the sound—but the camera can "hear" it.

b. The sound reflects off a person or object.

c. The reflected sound returns to the camera. Electronic parts in the camera "hear" the sound and figure out the distance.

d. The distance "message" goes to the lens. The lens turns. It focuses the camera perfectly and automatically.

REACHING OUT

Sound can echo through water as well as air. Echoes in water help ships and submarines find out how deep water is. To find out water depth by using echoes we use a system called sonar.

Sonar also helps locate schools of fish. In time of war, it helps locate enemy submarines.

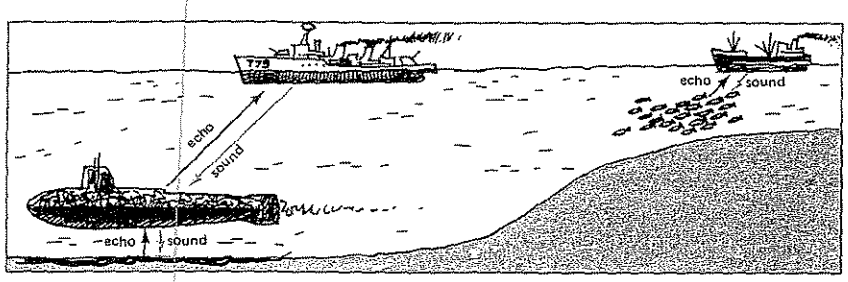


Figure F

This is how sonar works:

1. A ship sends a short-wave sound into the water.
2. When the sound hits the ocean floor, or a school of fish, or a submarine, the sound bounces back to the ship. The ship that sent the original sound gets back the echo.
3. An instrument aboard the ship measures how long the sound takes to make a round trip.

   This time is used to find the depth. How? You figure it out. It's really simple but, slightly tricky. So—don't rush. Think carefully.

What You Need To Know In water, sound travels about 1,500 meters per second.

Now solve these.

1. How deep is the water if the sound takes 2 seconds to reach bottom and bounce back? _____ meters
2. How deep for these time measurements?

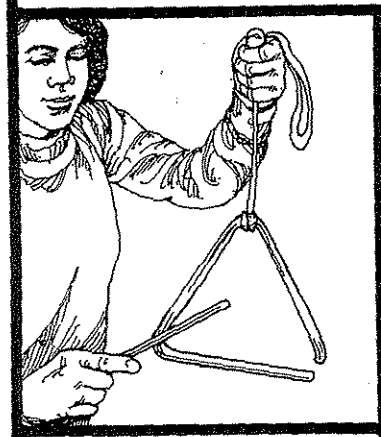
   a) 1 second? _____ d) 8 seconds? _____

   b) 10 seconds? _____ e) 3 seconds? _____

   c) 4 seconds? _____

WHAT IS PITCH?

6



HEINRICH HERTZ

pitch: how high or low a sound is

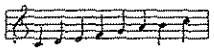
frequency of vibration: how often an object vibrates in one second

hertz: a unit that measures the frequency of vibration

AIM 6 What is pitch?

The roar of a lion, the squeak of a mouse. The tweet of a flute, the blast of a tuba. A gentle whisper, a deafening shout. Each of these is a different sound. There are many kinds of sounds. Each sound has its own properties. One of the properties of sound is called *pitch*.

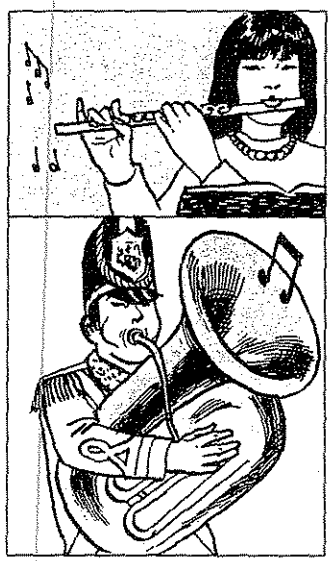
WHAT IS PITCH?



The best way to explain pitch is with a musical scale.

You probably know the musical scale. Sing it to yourself. Go ahead, *really* do it! Do, re, mi, fa, sol, la, ti, do! Notice that the notes become higher and higher.

The musical scale is made up of sounds of different pitches. Each sound has its own pitch. Pitch, then, is how *high* or *low* a sound is. Pitch is *not* how loud or soft a sound is.



WHAT CAUSES PITCH?

Pitch depends upon *how fast* an object vibrates in one second. We call this *frequency* [FREE kwun see] *of vibration*.

- The *faster* or more frequently an object vibrates, the *higher* is its pitch.
- The *slower* or less frequently an object vibrates, the *lower* is its pitch.

A flute sound has a *high* pitch. A tuba sound has a *low* pitch.

- A flute sound vibrates *faster* than a tuba sound.
- A flute sound has a faster frequency of vibration than a tuba sound.

ABOUT CYCLES

Frequency of vibration is measured with a unit called hertz. One hertz means one vibration per second.

One complete vibration is called a cycle. On the oscilloscope, one sound cycle shows up as one wave.

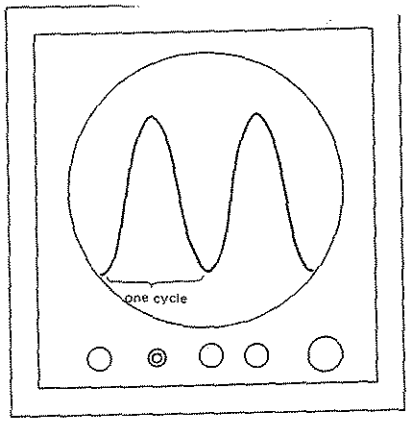


Figure A

1. How many cycles does Figure A show? _____
2. A high pitch has _____ cycles. (many, few)
3. A low pitch has _____ cycles. (many, few)

Two wave patterns are shown in Figures B and C. Study the patterns. Answer the questions. Use the figure letters in your answers.

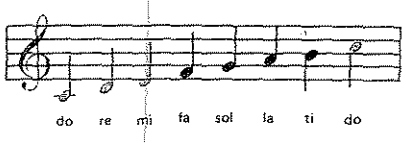
Figure B

Figure C

4. Which sound produces more cycles of vibrations? _____
5. Which sound produces fewer cycles? _____
6. Which sound vibrates *faster*? _____
7. Which sound vibrates *slower*? _____
8. a) Which sound is higher in pitch? _____
   b) How do you know? _____
9. a) Which sound is lower in pitch? _____
   b) How do you know? _____

IDENTIFYING SOUND WAVES

Four sound-wave patterns are shown in Figures D through G. Each one stands for a note on a musical scale.



- One pattern stands for the *first do*.
- One stands for *re*.
- One stands for *mi*.
- Still another stands for the *last do*.

Match the patterns to the notes. But first answer these questions.

1. A high-pitched sound vibrates _____ (faster, slower) than a low-pitched sound.
2. A high-pitched sound has _____ (fewer, more) cycles than a low-pitched sound.
3. A high-pitched sound has a _____ (shorter, longer) wavelength than a low-pitched sound.

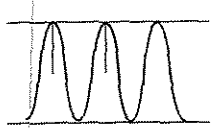


Figure D

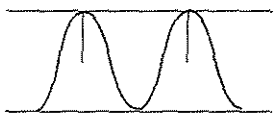


Figure E

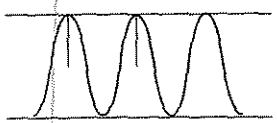


Figure F

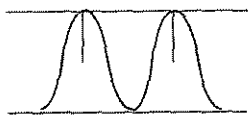


Figure G

4. The first do goes with the pattern in Figure _____ (D, E, F, G).
5. *Re* goes with the pattern in Figure _____ (D, E, F, G).
6. *Mi* goes with the pattern in Figure _____ (D, E, F, G).
7. The last do goes with the pattern in Figure _____ (D, E, F, G).

Let's compare the first do with the last do.

8. From your own experience, you know that the last do is also the _____ (first, last) do of the next _____ (higher, lower) scale.
9. With your metric ruler, measure the wavelengths of the first do and the last do.
   a) The wavelength of the first do measures _____ mm.
   b) The wavelength of the last do measures _____ mm.
   c) The wavelength of the last do is _____ (one half, twice) the wavelength of the first do.
   d) The last do vibrates _____ (twice as fast, half as fast) as the first do.
   e) The pitch of the last do is _____ (half, twice) the pitch as the first do.

COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

soft	lower	slower
frequency of vibration	high	loud
higher	faster	low
fast	different	

1. Pitch is how _____ or _____ a sound is.
2. Pitch is *not* how _____ or _____ a sound is.
3. Each note of the musical scale has a _____ pitch.
4. Pitch depends upon how _____ an object vibrates.
5. A high-pitched sound vibrates _____ than a low-pitched sound.
6. A low-pitched sound vibrates _____ than a high-pitched sound.
7. The faster an object vibrates, the _____ the pitch; the slower an object vibrates, the _____ the pitch.
8. A police whistle gives off a _____ pitched sound.
9. A tuba gives off a _____ pitched sound.
10. Another way of saying pitch is _____.

MATCHING

Match the two lists. Write the correct letter on the line next to each number.

1. _____ cycle
2. _____ high-pitched sound
3. _____ low-pitched sound
4. _____ musical scale
5. _____ hertz

a) many cycles
b) a unit that measures frequency of vibration
c) few cycles
d) one complete vibration
e) each note has a different pitch

REACHING OUT

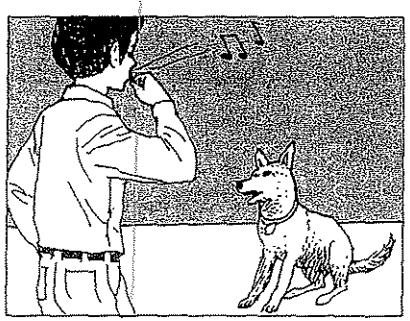


Figure H

A dog whistle has a very high pitch. You blow a dog whistle and your dog's ears pop up. But you do not hear the sound.

What does this show about pitch and hearing?

_____

_____

_____

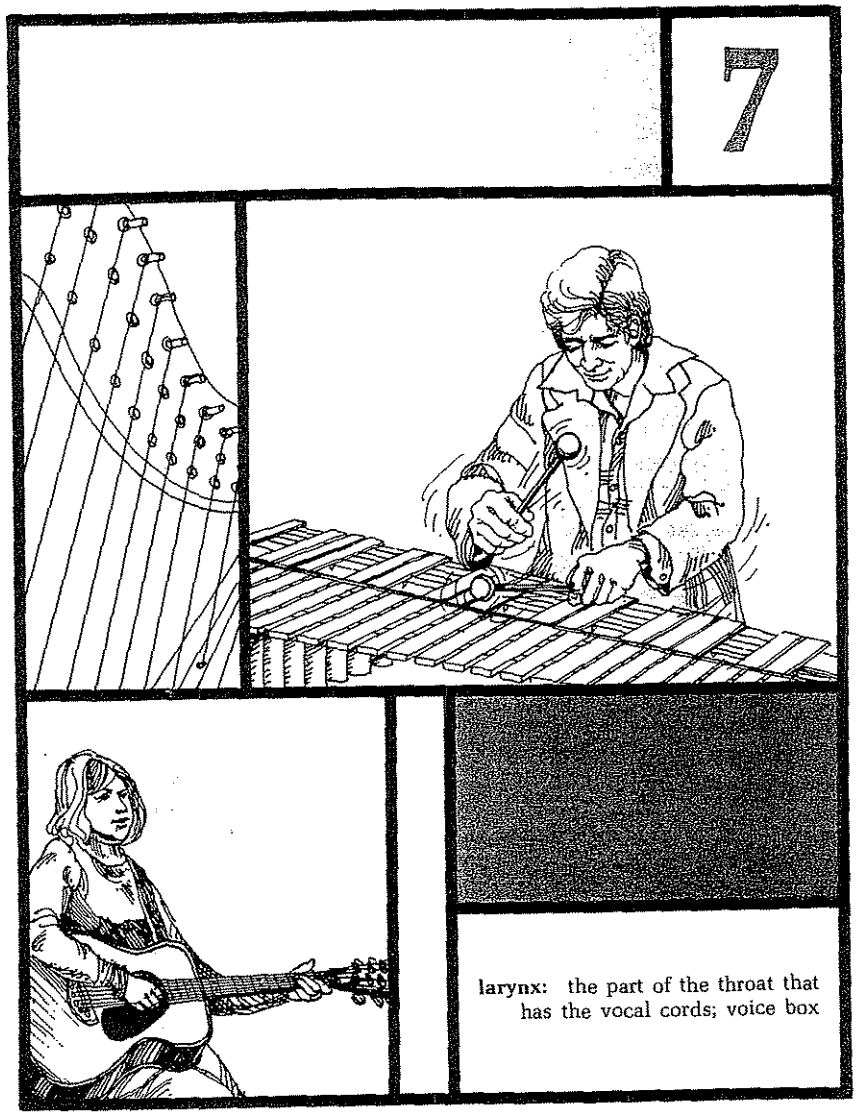
_____

WORD SCRAMBLE

Unscramble each of the following to form a word or term that you have read in this Aim.

1. THEGLAVWEN _____
2. LYCCE _____
3. THIPC _____
4. NECRFYQUE _____

HOW DOES PITCH CHANGE?



AIM 7 | How does pitch change?

Words are the most important part of speech. But *pitch* is important too. When you speak, the pitch of your voice keeps changing. Changes of pitch add meaning to words. They help deliver the message of what you wish to say.

Changes of pitch are also the most important part of music. Can you imagine a song that has only one pitch? Can you imagine a guitar or piano that could sound only one pitch? What a dull world it would be if there were no changes of pitch!

How does pitch change? You know that pitch depends upon the number of times a second an object vibrates. When an object vibrates faster, its pitch becomes *higher*. When an object vibrates slower, its pitch becomes *lower*.

To change pitch, you must change vibration speed. Here are some things that change vibration speed.

TIGHTNESS

- The *tighter* an object is, the *faster* it vibrates. Its pitch becomes *higher*.
- The *looser* an object is, the *slower* it vibrates. Its pitch becomes *lower*.

LENGTH

- The *shorter* an object is, the *faster* it vibrates. Its pitch becomes *higher*.
- The *longer* an object is, the *slower* it vibrates. Its pitch becomes *lower*.

THICKNESS

- The *thinner* an object is, the *faster* it vibrates. Its pitch becomes *higher*.
- The *thicker* an object is, the *slower* it vibrates. Its pitch becomes *lower*.

UNDERSTANDING PITCH CHANGES

Study Figures A through D and read the explanations. Answer the questions.

Pitch change and string tightness

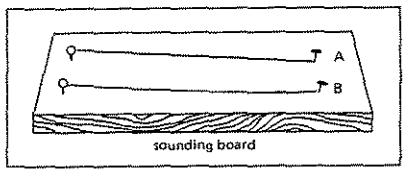


Figure A

In Figure A, strings A and B have the same thickness and length. A is tighter than B. You pluck the strings.

1. Which string . . .
   a) vibrates *faster*? _____ c) has a *higher* pitch? _____
   b) vibrates *slower*? _____ d) has a *lower* pitch? _____
2. The *tighter* an object is, the _____ (faster, slower) it vibrates.
3. The *looser* an object is, the _____ (faster, slower) it vibrates.
4. The *tighter* an object is, the _____ (higher, lower) is its pitch.
5. The *looser* an object is, the _____ (higher, lower) is its pitch.

Pitch change and length

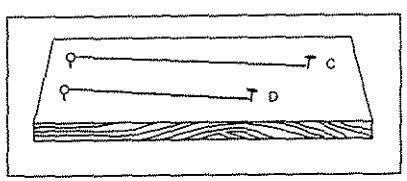


Figure B

In Figure B, strings C and D have the same thickness and the same tightness. But they are not the same length. You pluck the strings.

6. Which string . . .
   a) is *longer*? _____ d) vibrates *slower*? _____
   b) is *shorter*? _____ e) has the *higher* pitch? _____
   c) vibrates *faster*? _____ f) has the *lower* pitch? _____
7. The *longer* an object is, the _____ (slower, faster) it vibrates.
8. The *shorter* an object is, the _____ (slower, faster) it vibrates.

9. The *longer* an object is, the _____ its pitch.
higher, lower

10. The *shorter* an object is, the _____ its pitch.
higher, lower

11. How would you make C the same pitch as D? Underline two ways.

a) Tighten C. b) Loosen C. c) Tighten D. d) Loosen D.

Pitch change and thickness

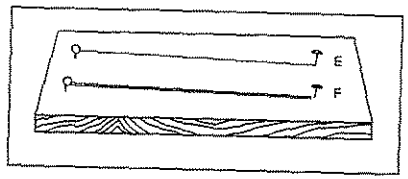


Figure C

In Figure C, strings E and F have the same length and the same tightness. But one string is thicker than the other. You pluck the strings.

12. Which string . . .

a) is *thinner*? _____

b) is *thicker*? _____

c) vibrates *faster*? _____

d) vibrates *slower*? _____

e) has the *highest* pitch? _____

f) has the *lowest* pitch? _____

13. The *thinner* an object is, the _____ it vibrates.
slower, faster

14. The *thicker* an object is, the _____ it vibrates.
slower, faster

15. The *thinner* an object is, the _____ is its pitch.
higher, lower

16. The *thicker* an object is, the _____ is its pitch.
higher, lower

17. How would you make E the same pitch as F? Underline two ways.

a) Tighten E. b) Loosen E. c) Tighten F. d) Loosen F.

Figure D shows the strings of a piano.

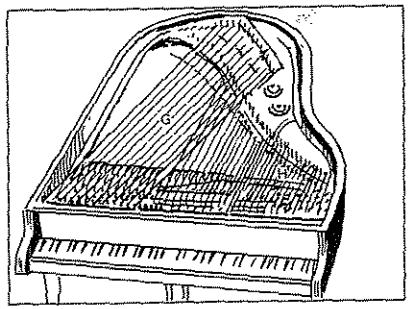


Figure D

18. a) Which group of strings produces the *higher* notes? _____

b) How do you know? _____

19. a) Which group of strings produces the *lower* notes? _____

b) How do you know? _____

HOW VOICE PITCH CHANGES

Voice is produced in the *voice box*, or *larynx* [LAR ingks]. The larynx contains the vocal cords. (You have seen the vocal cords in Aim 1.) The vocal cords can change shape and tightness.

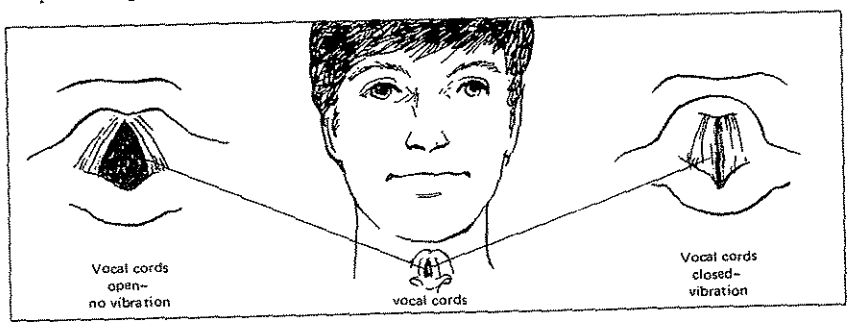


Figure E

When you are not speaking, the cords are not close together. They do not vibrate.

When you are speaking, the cords are close together. Air passing them from your lungs makes the cords vibrate. The vibrations cause sound.

As you speak, the tightness of the cords changes. The cords also move slightly closer or farther apart. These changes cause changes in pitch.

FILL IN THE CHART

How would the pitch of a string change if you did the following things? Check the correct box.

Description	Pitch Becomes Higher	Pitch Becomes Lower
1. loosen string		
2. increase vibration speed		
3. lengthen string		
4. decrease vibration speed		
5. shorten string		
6. tighten string		

REACHING OUT

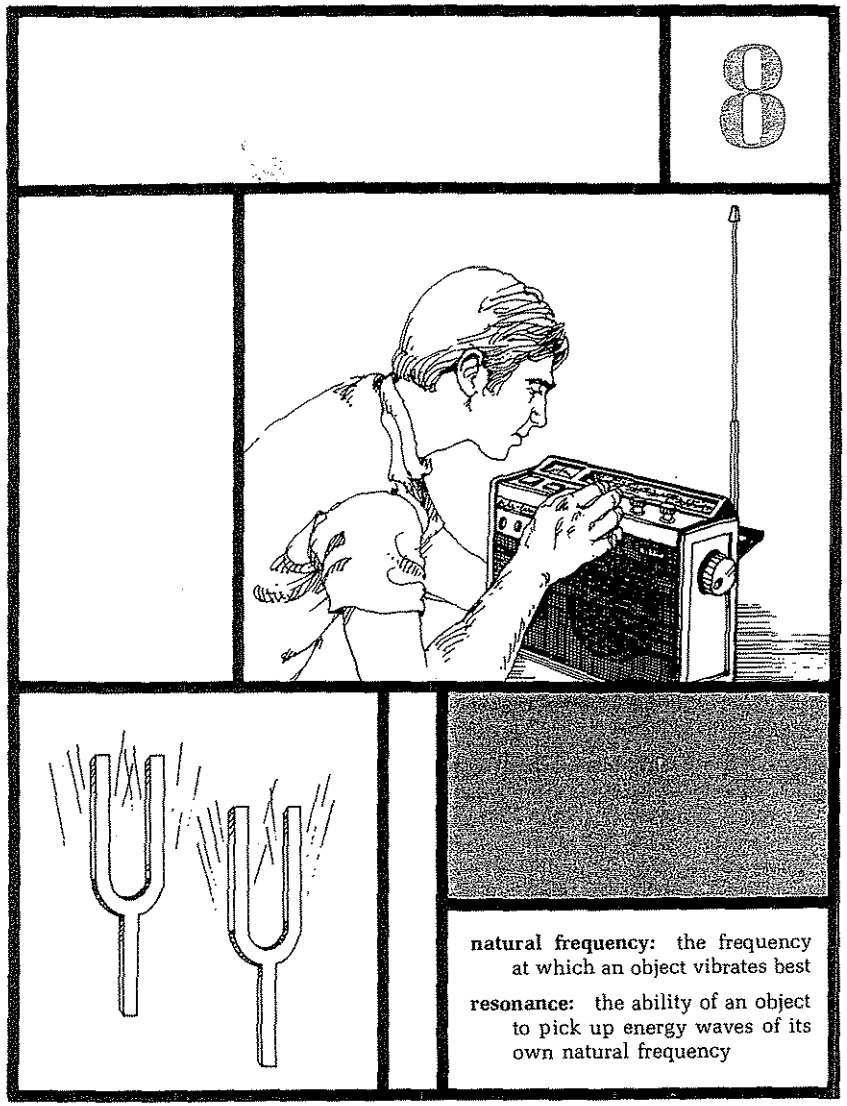
What causes your voice to be louder and softer?

_____

_____

_____

WHAT IS RESONANCE?



AIM 8 What is resonance?

Did this ever happen to you? You are listening to your favorite music station. Your room "is alive with the sound of music." A certain note is hit—and some object in your room vibrates. It doesn't happen with every note, just a *certain* note.

Why does that happen? It can be explained in the following way.

Every object has its own frequency of vibration. This is called its *natural frequency*. For example, the natural frequency of one object may be *300 hertz*—or 300 vibrations per second. For another object, it may be *325 hertz*.

A sound of a certain natural frequency will cause an object of the same natural frequency to vibrate strongly. The second object picks up the vibration energy. It vibrates "in sympathy" with the first object. We say that both objects are "in tune" with each other.

The ability of an object to pick up energy of its own natural frequency is called *resonance* [REZ uh nance].

Resonance is important in many ways. For example, every radio station broadcasts on a different frequency. When you "tune" your radio, you *match* the frequency of the radio station.

Resonance can also be annoying, especially when it causes unwanted vibrations. Resonance can be destructive, too. It has been known to crack windows and other glass objects. Some resonance frequencies can make you feel sick.

UNDERSTANDING RESONANCE

Study Figure A. Answer the questions.

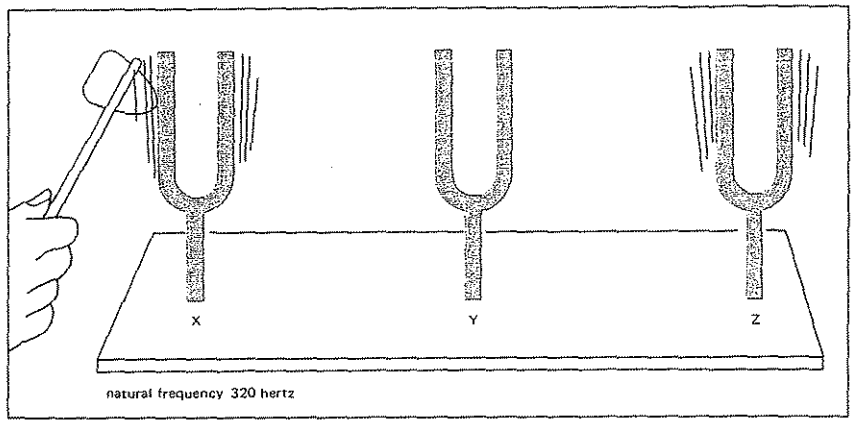


Figure A

1. Which tuning fork is being struck? _____
2. What is its *natural frequency of vibration*? _____
3. a) Which of the other forks has the same natural frequency? _____
   b) How do you know? _____
4. a) Which other fork does *not* have the same natural frequency? _____
   b) How do you know? _____
5. Which fork would you strike to make fork X vibrate? _____
6. a) Will striking fork Y make fork X vibrate? _____
   b) Why? _____
7. a) Will striking fork Z make fork X vibrate? _____
   b) Why? _____
8. a) Will striking fork Z make fork Y vibrate? _____
   b) Why? _____
9. Which forks are in tune with each other? _____
10. An object will pick up energy of its own frequency. What is this called?

    _____

YOU CAN PRODUCE RESONANCE

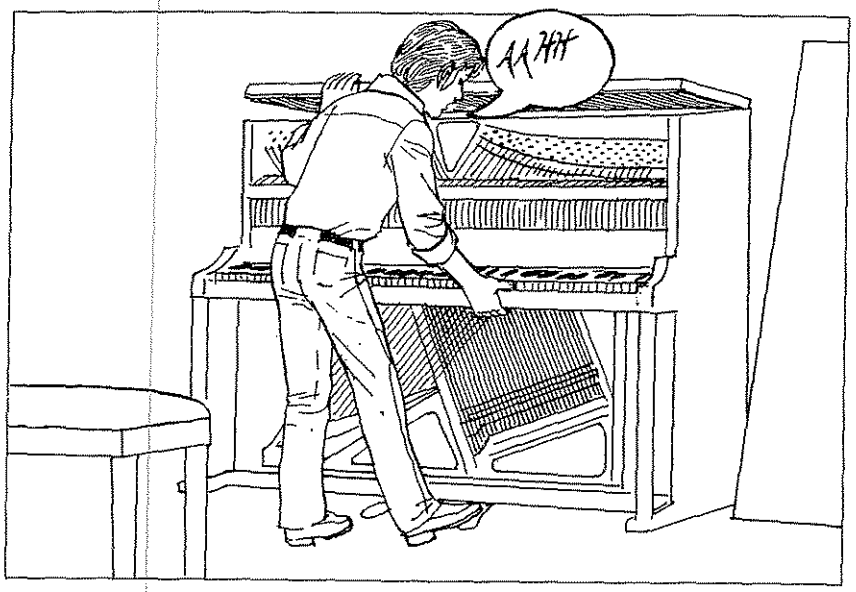


Figure B

Try to get to a piano. If possible, open it so that you can see the strings.

- Press down the pedal on the far right. This frees the strings so they can vibrate freely.

- Sing a single note—like a-a-h-h—but loudly. The string that matches the frequency of that note will vibrate. It will "sing back" to you.

For question 1, circle the correct answer.

1. How can you make a *different* string vibrate?

   a) Change your loudness.

   b) Change your pitch.

2. A piano has 88 keys.

   a) How many pitches does a piano have? _____

   b) How many natural frequencies does a piano have? _____

COMPLETING SENTENCES

Complete the sentences with the choices below.

lower	natural	same
sympathy	vibrations	higher
pitch	resonance	frequency
vibrate strongly	hertz	

1. Every sound is caused by _____.
2. The number of times a second an object vibrates is called its _____ of vibration.
3. Frequency of vibration determines the _____ of a sound.
4. Frequency of vibration is measured in a unit called _____.
5. The slower the frequency, the _____ the pitch. The faster the frequency, the _____ the pitch.
6. The frequency at which an object vibrates best is called its _____ frequency.
7. More than one object can have the _____ natural frequency.
8. A sound of a certain natural frequency can cause an object of the same natural frequency to _____.
9. An object will vibrate strongly when it absorbs energy of its own frequency. This is called _____.
10. Resonance causes objects to vibrate "in _____" with each other.

MATCHING

Match the two lists. Write the correct letter on the line next to each number.

1. _____ hertz		a) best vibration speed
2. _____ natural frequency		b) no resonance produced
3. _____ resonance		c) caused by sympathetic vibration
4. _____ 288 hertz sound and 288 hertz object		d) vibrations per second
5. _____ 288 hertz sound and 320 hertz object		e) resonance produced

TRUE OR FALSE Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. _____ Every pitch has its own frequency.
2. _____ A change in frequency changes pitch.
3. _____ Every object has its own best frequency.
4. _____ The frequency at which an object vibrates best is called its *wave height*.
5. _____ Only one object can have a certain natural frequency of vibration.
6. _____ Only a musical string has a natural frequency of vibration.
7. _____ A dinner plate has a natural frequency of vibration.
8. _____ Objects that vibrate at the same frequency are "out of tune" with one another.
9. _____ When a sound reaches an object with the same natural frequency it produces sympathetic vibrations.
10. _____ Sympathetic vibrations produce resonance.

REACHING OUT

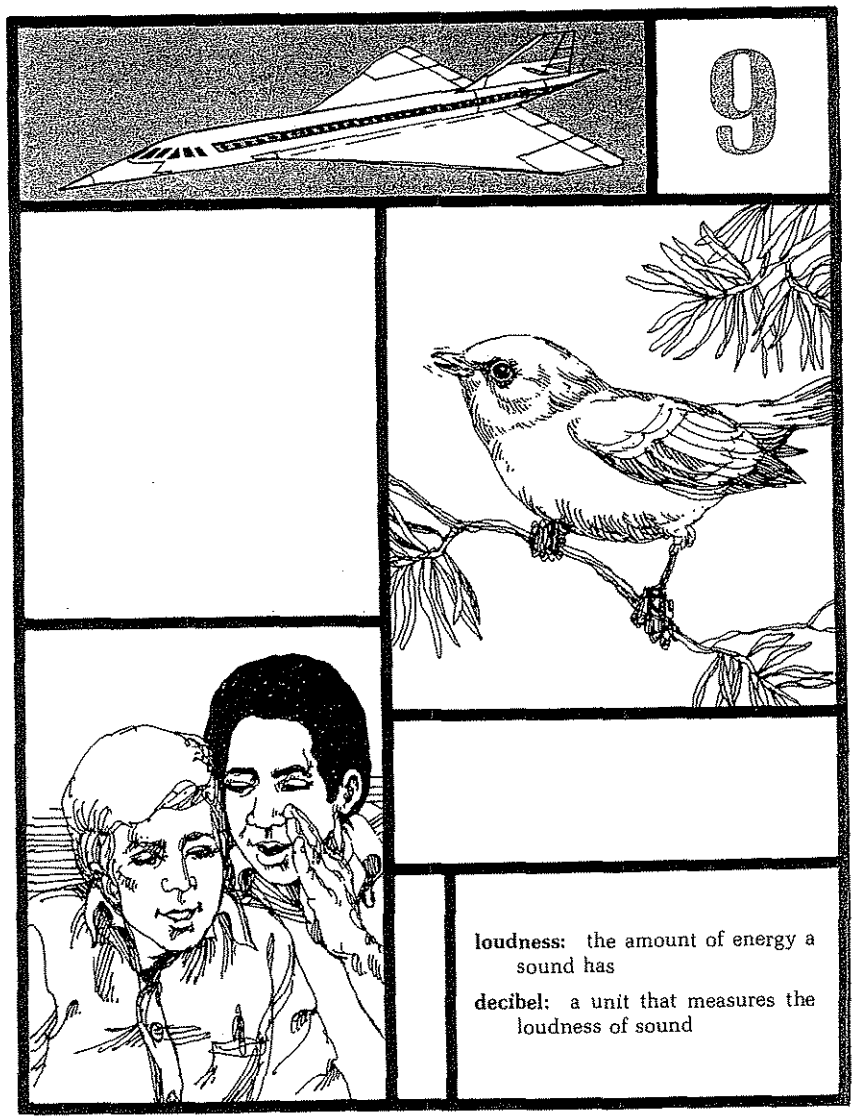
How does the distance between a vibrating object and a resonating body affect the loudness of the resonance?

_____

_____

_____

WHAT IS LOUDNESS?



AIM 9 What is loudness?

Sound has *pitch*. Pitch tells us how high or how low a sound is—like a musical note. Sound also has *loudness*.

There is a wide range of loudness. Some sounds, like a whisper or the chirp of a bird, have a *low* degree of loudness. They are "soft" sounds. Other sounds, like the roar of a jet or an explosion, have a *high* degree of loudness. In fact, some sounds are *so* loud, we have to cover our ears.

During the day you control different degrees of loudness. You change the volume of your radio or TV. You change the loudness of your voice. Sometimes you're told, "Speak up. I can't hear you." Other times it's, "Please lower your voice." Sound familiar? And what about this one? "Please lower your radio. It's blasting my eardrums!"

What causes loudness?

Pitch, you remember, depends upon frequency. The frequency is the number of times a second an object vibrates.

Loudness is different. Loudness depends upon the *amount of energy* a sound has. The greater the energy, the greater the loudness.

Loudness is measured in *decibels* [DES uh belz]. The *higher* the decibel number, the *louder* the sound.

Decibel values start at 0 (zero). A sound of zero decibels is the starting point of human hearing. A sound of 140 decibels may hurt our ears. For example, do you play your radio or stereo very loudly? Listening to very loud music over a long period of time may reduce your hearing—permanently.

UNDERSTANDING LOUDNESS

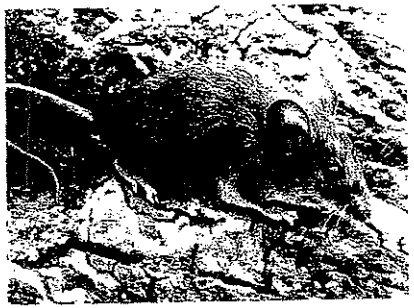


Figure A

Everyone knows that a lion makes a different sound from that of a mouse. Think of the sound each one makes. Then answer the questions below. Fill in each space with either *lion* or *mouse*.

1. *Higher-pitched* sounds are made by the _____.
2. *Lower-pitched* sounds are made by the _____.
3. *Faster frequency* sounds are made by the _____.
4. *Slower frequency* sounds are made by the _____.
5. *Lower decibel* sounds are made by the _____.
6. *Higher decibel* sounds are made by the _____.
7. *Stronger sound energy* is produced by the _____.
8. *Weaker sound energy* is produced by the _____.

LOUDNESS AND THE OSCILLOSCOPE

You can "see" loudness on an oscilloscope.

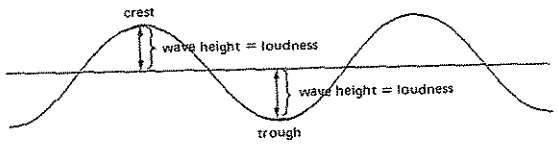


Figure B

The wave *height* shows how loud a sound is.

Wave height is measured from the mid-line of the wave to the crest or to the trough.

- The *higher* the wave height, the *louder* is the sound.
- The *lower* the wave height, the *softer* is the sound.

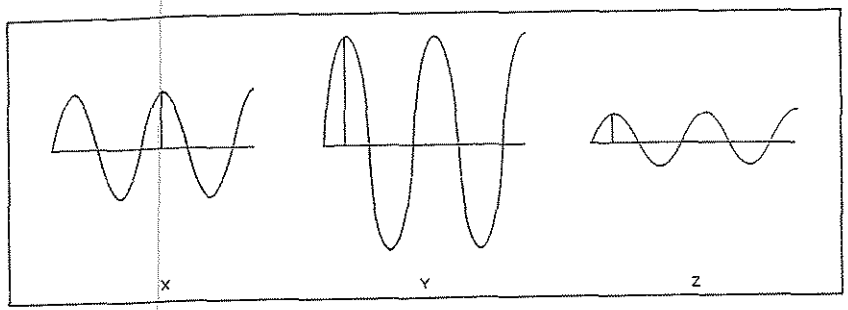


Figure C

Look at the three sets of waves in Figure C. Use your metric ruler to measure the heights of the waves. Now answer these questions with X, Y, or Z.

1. The wave height of wave X is _____ mm.
2. The wave height of wave Y is _____ mm.
3. The wave height of wave Z is _____ mm.
4. Which wave has the *greatest* wave height? _____
5. Which wave has the smallest wave height? _____
6. Which sound would be the loudest? _____
7. Which sound would have the highest decibels? _____
8. Which sound would be the softest? _____
9. Which sound would have the lowest decibels? _____

FILL IN THE CHART

The chart lists the average number of decibels that some common sounds have. Four decibel readings have been left out.

One wave crest for each of the missing readings is shown in Figures D through G. Read the height of each wave. Then mark down the correct decibel reading on the chart.

Sound	Average Number of Decibels
whisper	15
quiet office	
classroom	35
automobile	
conversation	
light street traffic	65
heavy street traffic	
automobile horn	100
loud thunder	110

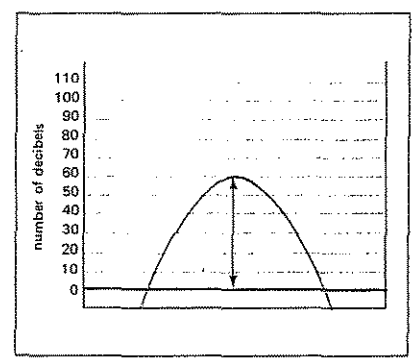


Figure D *Conversation*

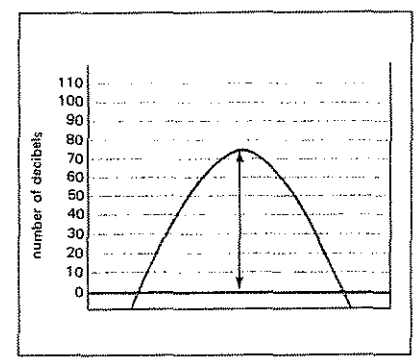


Figure E *Heavy street traffic*

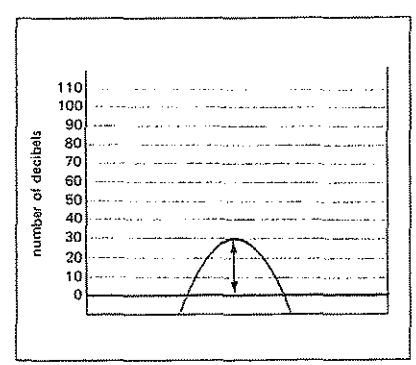


Figure F *Quiet office*

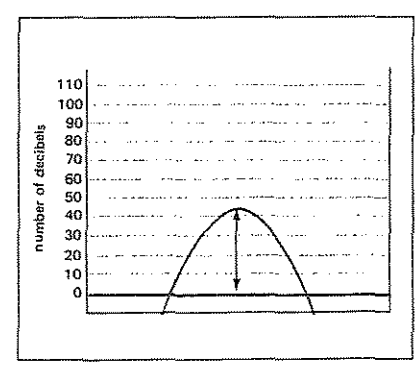


Figure G *Automobile*

COMPLETING SENTENCES

Complete the sentences with the choices below.

how fast	loud	the amount of energy
decibels	less	hertz
wave height	loudness	soft
more	pitch	

1. How high or low a sound is (like a note on the musical scale), is called _____.
2. Pitch depends upon _____ an object vibrates.
3. Another way of saying "vibrations per second" is _____.
4. The property of sound discussed in this Aim is _____.
5. Loudness depends upon _____ a sound has.
6. A loud sound has _____ energy than a soft sound.
7. A soft sound has _____ energy than a loud sound.
8. Loudness is measured in _____.
9. A high-decibel sound is a _____ sound. A low-decibel sound is a _____ sound.
10. The part of a wave that shows loudness is its _____.

REACHING OUT

The sound of a siren changes. Describe the sound after you switch it on. Then describe the sound after you switch it off. (Use the terms *pitch* and *decibels*.)

1. Siren switched *on*. _____
2. Siren switched *off*. _____

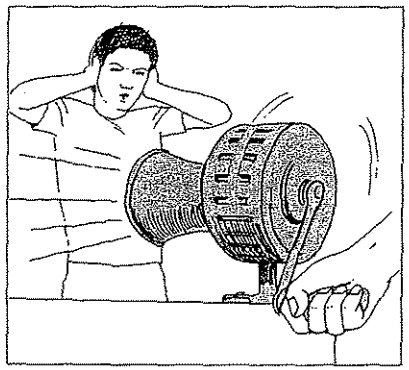
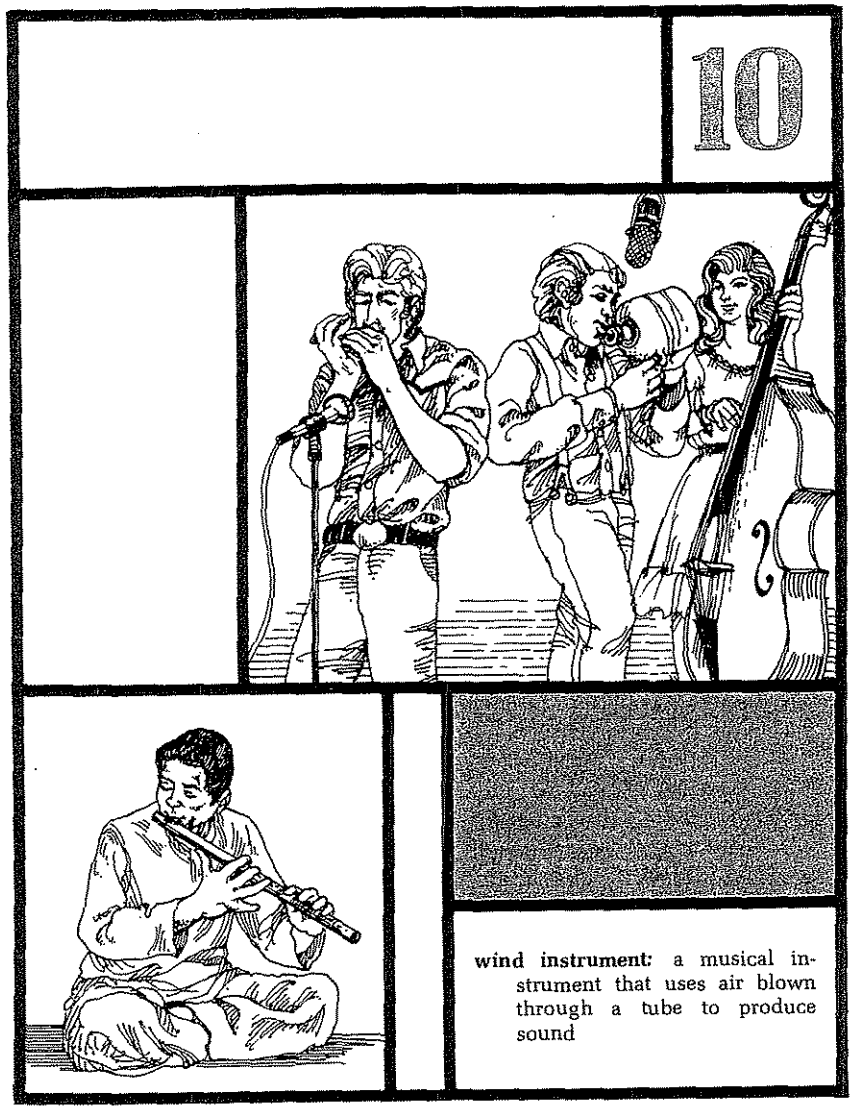


Figure H

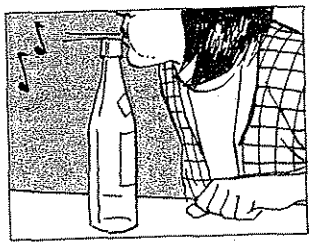
WHAT SOUNDS DO COLUMNS OF AIR PRODUCE?



AIM 10 | What sounds do columns of air produce?

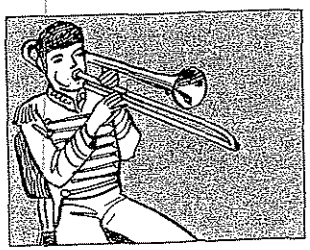
Did you ever blow across the opening of an empty bottle? The moving air made the air in the bottle vibrate. This vibration produced a sound.

If you blew across a short bottle, you produced a *high-pitched* sound.

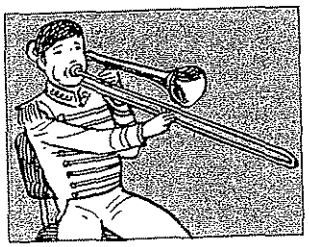


If you blew across a taller bottle, you produced a *lower-pitched* sound.

A wind instrument—like a trombone—works in much the same way. The musician blows into the mouthpiece. The musician's lips make the air vibrate. A sound is produced.



To produce *high-pitched* sounds, the musician pulls the slide in. This *shortens* the column of air.



To produce a *lower-pitched* sound, the musician pushes the slide out. This *lengthens* the column of air.

- Short air columns produce high-pitched sounds.
- Long air columns produce low-pitched sounds.

PITCH AND COLUMNS OF AIR

Figure A shows four columns of air. Look at the figure. Then answer the questions.

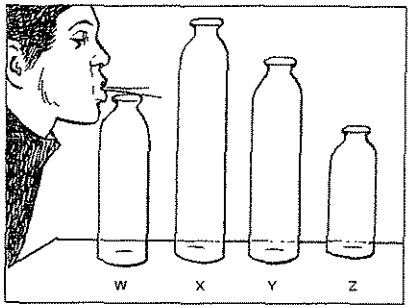


Figure A

1. a) Which is the tallest? _____

   b) Which is the shortest? _____

2. a) Which will produce the *highest*-pitched sound? _____

   b) Why? _____

3. a) Which will produce the *lowest*-pitched sound? _____

   b) Why? _____

Underline the correct answer.

4. Pitch depends upon
   a) the number of vibrations per second.
   b) the force of the vibrations.

5. a) In which column will the air vibrate the fastest? _____

   b) In which column will the air vibrate the slowest? _____

Instruments and changing air-column size

Figure B

The flute, clarinet, and saxophone are *wind* instruments.

Covering different holes changes the length of the air columns.

Figure C

Valves change the length of the air column in the trumpet and French horn.

6. Look back to the first page of this Aim. What is moved to change the length of the air column in a trombone? _____

COMPLETING SENTENCES

Complete the sentences with the choices below.

faster	low	valves
wind	clarinet	slower
holes	high	flute
length	vibrating	

1. Sound is caused by _____ matter.
2. A musical instrument that makes sounds by means of a vibrating column of air is called a _____ instrument.
3. The pitch of a wind instrument depends upon the _____ of its air column.
4. A long air column produces a _____-pitched sound.
5. A short air column produces a _____-pitched sound.
6. High-pitched sounds vibrate _____ than low-pitched sounds.
7. Low-pitched sounds vibrate _____ than high-pitched sounds.
8. Examples of wind instruments are the _____ and the _____.
9. The length of the air column in a flute is controlled by _____.
10. The length of the air column in a trumpet is controlled by _____.

THROW ONE OUT

In each of the following sets of terms, one of the terms does not belong. Circle that term.

1. long air column high pitch low pitch
2. short air column high pitch low pitch
3. wind instrument flute drum
4. vibrating matter no sound sound
5. wave energy wave frequency pitch

TRUE OR FALSE

Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. _____ Pitch depends upon the energy of a sound wave.
2. _____ All sounds vibrate at the same speed.
3. _____ The faster the vibration, the higher the pitch.
4. _____ The slower the vibration, the lower the pitch.
5. _____ Only vibrating solids produce sounds.
6. _____ Vibrating air molecules can produce sound.
7. _____ Musical instruments that make a column of air vibrate are called *string* instruments.
8. _____ A short column of air produces a higher-pitched sound than a long column of air.
9. _____ Air in a short column vibrates faster than air in a long column.
10. _____ Strong vibrations produce high-pitched sounds.

REACHING OUT

There are three classes of musical instruments: *wind* instruments (woodwinds and brasses), *string* instruments, and *percussion* instruments.

You have seen wind instruments earlier in this Aim.

Figure D

In string instruments, strings are plucked with fingers or rubbed with a bow.

Figure E

In percussion instruments, tight skins (or skin-like materials), blocks, thin metal or wires are struck.

Several instruments are listed below. Identify each as either *string*, *wind*, or *percussion*. Write your answer next to each instrument.

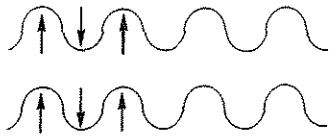
	Instrument	Class
1.	Oboe	
2.	Cymbals	
3.	Tuba	
4.	Violin	
5.	Mandolin	
6.	Bassoon	
7.	Xylophone	
8.	Bongos	
9.	Banjo	
10.	Piccolo	
11.	Tambourine	

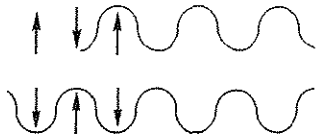
Figure F

12. To what class does the piano belong? _____

WHAT HAPPENS WHEN SOUNDS COMBINE?

11





interference: the combining of two or more sounds

in-phase waves: waves that combine to produce a stronger wave

out-of-phase waves: waves that combine to produce a weaker wave

AIM 11 What happens when sounds combine?

Every sound has its own energy wave. When two or more sounds happen at the same time, their waves combine. This is called *interference* [in ter FEAR ens].

Sound interference affects *loudness*. It can make a sound louder or softer. It depends upon the *pitches* of the combined sounds.

- Interference that produces a *louder* sound is called *constructive* interference.
- Interference that produces a *softer* sound is called *destructive* interference.

CONSTRUCTIVE INTERFERENCE occurs when the crests and troughs of combining waves are lined up in the same direction.

This is an example of constructive interference:

Sound 1
Sound 2

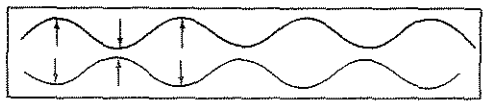
These waves are in step. We say they are *in phase*.

Waves that are in phase *help* each other. They combine to produce a *louder* sound.

DESTRUCTIVE INTERFERENCE occurs when the crests and troughs of combining waves are lined up in *opposite* directions.

This is an example of *destructive* interference:

Sound 1
Sound 2



These waves are *out* of step. We say they are *out of phase*.

Waves that are out of phase work *against* each other. They combine to form a *softer* sound.

UNDERSTANDING INTERFERENCE

A tuning fork produces a pure sound. A pure sound has just *one* frequency.

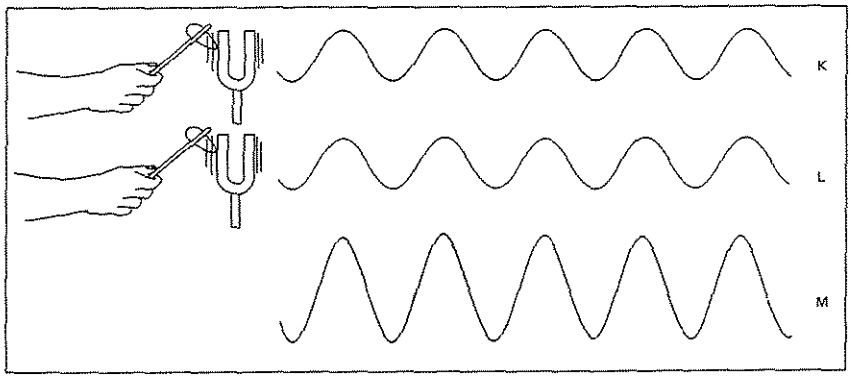


Figure A

In Figure A, tuning forks K and L are producing pure sounds of the *same* frequency. They interfere with one another. The new sound M is produced.

1. Look at the waves produced by K and L. Their crests and troughs _____ lined up. (are, are not)
2. All the waves are _____ phase. (in, out of)
3. The waves _____ each other. (help, work against)
4. This is _____ interference. (constructive, destructive)
5. The sound becomes _____. (louder, softer)

From Figure A you can draw a conclusion: Sounds of the same pitch made at the same time are *in phase*. They produce a *louder* sound.

QUESTION! What happens when sounds of *different* pitches combine?

When sounds of different pitches combine, they produce *both in-phase and out-of-phase* interference. The sound becomes louder—then softer, louder—then softer, over and over again. This causes "pulses" of sounds called *beats*. (These are *not* the same beats as drumbeats.)

Look at Figure B.

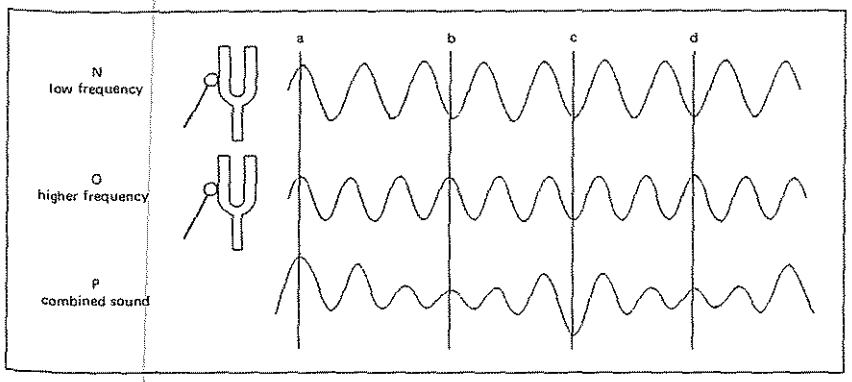


Figure B

In Figure B, tuning forks N and O are producing pure sounds. Each one is a *different* frequency. They interfere with each other. The new sound P is produced.

Look at the waves produced by N and O.

6. Are all the crests and troughs *in* phase? _____

7. Are all the crests and troughs *out* of phase? _____

8. Which parts of the waves are exactly in phase? _____ (give letter(s))

9. Which parts of the waves are exactly *out* of phase? _____ (give letter(s))

10. A part of a wave that is in phase produces a _____ (louder, softer) sound.

11. A part of a wave that is out of phase produces a _____ (louder, softer) sound.

12. Which parts of the waves produce *louder* sounds? _____ (give letters)

13. Which parts of the waves produce *softer* sounds? _____ (give letters)

The combined waves produce a sound that becomes louder, then softer—louder, then softer. They produce *pulses* of sound.

14. What are these pulses called? _____

15. Beats are caused by combined sounds of _____ (equal, unequal) frequencies.

BEATS ME!

Four pairs of pure sound waves are shown in Figures C through F.

Each pair is being sounded at the same time.

Some pairs *will* produce beats. Some will *not*. Which is which? Under each figure write: "Beats" or "No beats."

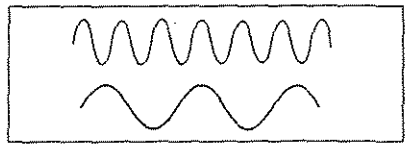


Figure C

1. _____

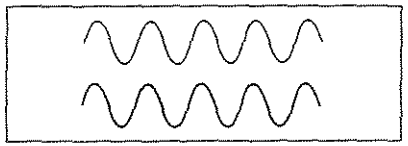


Figure D

2. _____

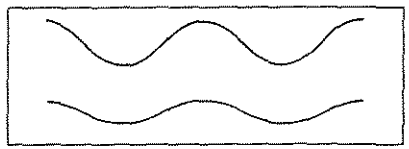


Figure E

3. _____

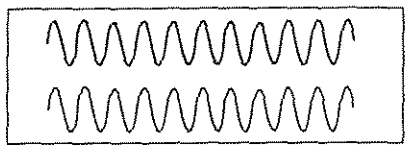


Figure F

4. _____

Beats may occur a few times a second—or, *many* times a second. How beats affect us depends upon how often they happen.

Most people are not annoyed by sounds that produce up to 5 or 6 beats per second.

But sounds with more than 6 beats per second become unpleasant. The unpleasantness becomes greater as the number of beats increases, but *only up to 30 beats per second.*

Figure G

Beyond 30 beats per second, the beats start to "blend." Most people do not hear separate beats. The unpleasantness becomes less.

Figure H

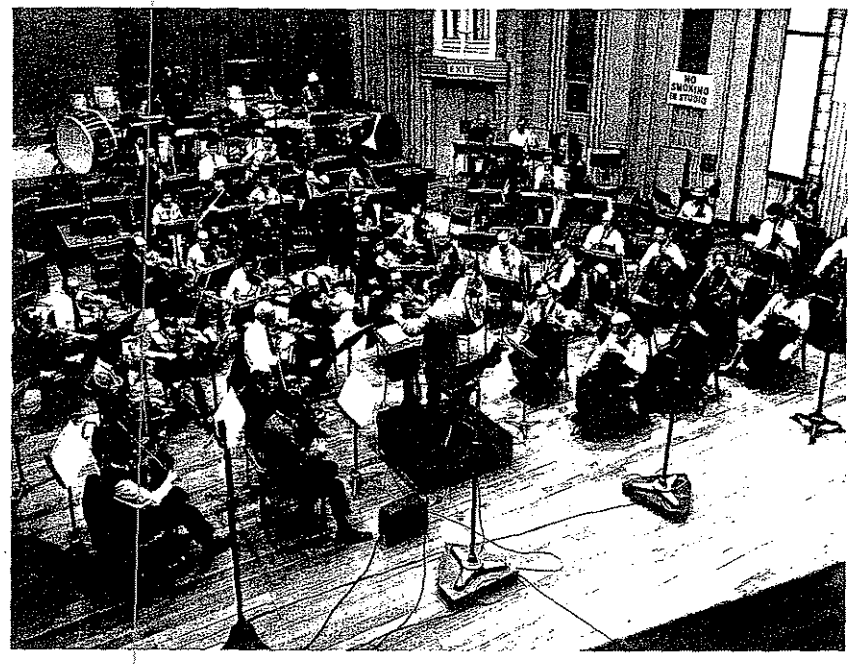


Figure I

Beats are unwanted in music. Musicians try to avoid beats. They do this by tuning their instruments to the same frequency. Sounds of the same frequency do not produce beats.

COMPLETING SENTENCES

Complete the sentences with the choices below. One of these may be used three times. One may be used twice.

louder	interfere	out of
in	softer	loudness
beats		

1. Sounds that combine _____ with one another.
2. Sound interference affects _____.
3. Constructive interference produces a _____ sound.
4. Destructive interference produces a _____ sound.
5. Matched crests and troughs are said to be _____ phase.
6. Unmatched crests and troughs are said to be _____ phase.
7. In-phase waves produce _____ sounds.
8. Out-of-phase waves produce _____ sounds.
9. Sounds of the same pitch made at the same time produce only a _____ sound.
10. Sounds of different pitches made at the same time produce pulses of loud and soft sounds. These pulses are called _____.

FIGURING BEATS

How do you figure beats? It's simple! Just find the difference between the two combining frequencies. This tells us the number of beats per second.

For example: A sound of 200 vibrations per second combines with a sound of 210 vibrations per second. This produces a sound with 10 beats per second. (210 − 200 = 10.)

Several pairs of combining sounds are listed on page 68. Each pair produces beats.

- Figure out the number of beats.
- Tell whether the number of beats is annoying.

Write your answers on the chart.

	Combining Frequencies	Number of Beats Produced per Second	Are the Beats Annoying? (Yes or No)
1.	384 and 404		
2.	324 and 328		
3.	480 and 467		
4.	622 and 600		
5.	256 and 262		
6.	576 and 604		
7.	360 and 368		
8.	368 and 365		
9.	325 and 345		
10.	381 and 384		

SPELL THE MISSING WORD Fill in the missing letters to spell the terms that fit the definitions.

When you have answered correctly, you will spell another term in the box.

1. ___ e ___ i ___ e ___
2. ___ h ___ r ___ z ___
3. ___ h ___ s ___
4. ___ s ___ f ___

1. a unit that measures how loud a sound is
2. a unit that tells how many vibrations per second
3. out-of-_____ waves
4. not loud

WHAT ARE OVERTONES?

12

fundamental: the lowest pitch a vibrating object can make

overtone: a higher-pitched tone than the fundamental ; it is produced by the same object that produced the fundamental

AIM 12 | What are overtones?

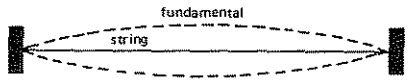
A song is played on the piano. The same song is played on a guitar, trumpet, or flute. The pitches or *tones* are the same. Yet each instrument "sounds" different. You have no trouble telling them apart. Each instrument has its own special kind, or *quality*, of sound.

Sound quality helps us to recognize all sorts of sounds. Take voices, for example. A friend calls to you from around the corner. Who is calling? John? Maria? Tom? Carol? You recognize the voice from its *quality*.

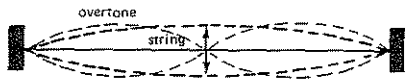
How does a sound get its special quality?

A tuning fork vibrates with only one frequency. But most sound-making bodies do not. Most sound-making bodies vibrate at different speeds at the same time. Each speed produces its own pitch.

Take a vibrating string, for example.



The *entire* string vibrates. This produces a certain pitch.



At the same time, parts or *sections* of the string vibrate *faster*. This produces a *higher* pitch.

- The tone produced by the *entire* string is called the *fundamental* tone. It is the lowest tone that string can make.
- The higher tone produced by the separate sections is called the *overtone*.

The pitch of the overtone depends upon how many sections vibrate. The greater the number of vibrating sections, the higher the pitch.

The fundamental tone and overtone blend. Together, they give a sound its *quality*. Many sounds have more than one overtone pitch.

Different combinations of fundamental tones, overtones, and loudness produce sounds of different qualities.

UNDERSTANDING OVERTONES

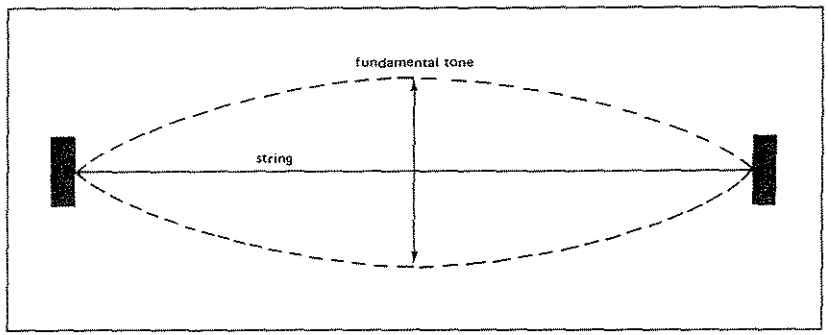


Figure A

If the entire string vibrates in only one section, it produces only a *fundamental* tone. There is no overtone.

1. a) What kind of tone is the string in Figure A producing? _____

   b) How do you know? _____

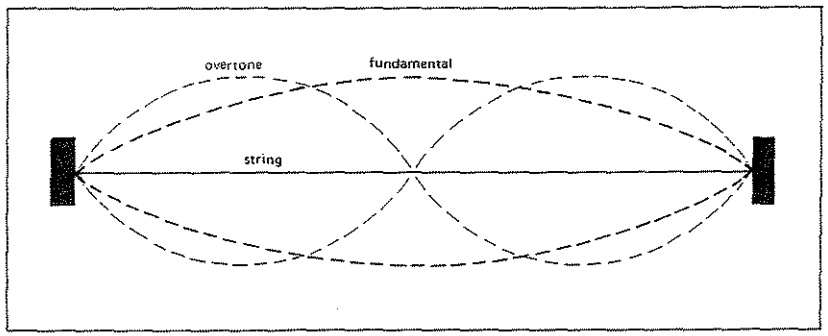


Figure B

If a string vibrates in sections, it produces a *fundamental and* an *overtone*.

The string in Figure B is producing an overtone.

2. How many separate overtone sections are vibrating? _____

In Figure B, the number of vibrating overtone sections is *twice* the number of the fundamental. The fundamental vibrates in one section. But the overtone vibrates in two sections or *loops*. This means that each overtone loop vibrates twice as fast as the fundamental.

Suppose, for example, the fundamental has 200 vibrations per second (vps). The overtone, then, vibrates at *twice* that speed. It vibrates *400* times per second. Its pitch (how high the note is on the musical scale) is also twice the pitch of the fundamental.

FUNDAMENTAL × NUMBER OF OVERTONE LOOPS = OVERTONE

200 vps { vibrations per second (vps) } × 2 { the number of times higher the overtone pitch is } = 400 vps { vibrations per second (vps) }

Solve the following problems.

3. If the fundamental has 200 vps, how fast would the overtone vibrate if the string vibrates in

   a) 3 sections? _____

   b) 4 sections? _____

   c) 5 sections? _____

4. How many times higher would the overtone pitch be if the string vibrates in

   a) 3 sections? _____

   b) 4 sections? _____

   c) 5 sections? _____

5. The more sections that vibrate, the _____ (higher, lower) the pitch of the overtone.

6. The pitch of an overtone is always _____ (higher, lower) than the pitch of the fundamental.

COUNTING SECTIONS

Four groups of overtone waves are shown in Figures C through F. Study them. Then answer the questions.

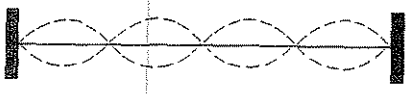


Figure C

Figure D

Figure E

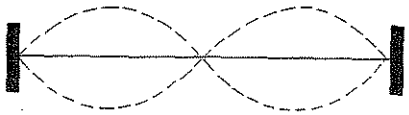


Figure F

1. How many vibrating sections produced the waves in . . . .

   a) Figure C? _____ c) Figure E? _____

   b) Figure D? _____ d) Figure F? _____

   One fundamental produced each of these overtones.

2. a) Which overtone has the *highest* pitch? _____

   b) How do you know? _____

3. a) Which overtone has the *lowest* pitch? _____

   b) How do you know? _____

Now let's change the fundamental!

The chart lists two different fundamentals for *each* overtone shown in Figures C through F. Figure out the number of vibrations for each overtone.

Write your answers in the chart.

Overtone	Fundamental vibrations per second	Overtone vibrations per second
Figure C	250	
	175	
Figure D	320	
	500	
Figure E	200	
	250	
Figure F	256	
	288	

4. Which overtone has the *highest* pitch?

   The one that vibrates _____ per second.

5. Which overtone has the *lowest* pitch?

   The one that vibrates _____ times per second.

COMPLETING SENTENCES

Complete the sentences with the choices below. One of these may be used twice.

pitch	quality	lowest
higher	fundamental	loudness
overtone	fundamental tones	overtones
separate sections	different speeds	

1. Most vibrating objects vibrate at _____ at the same time.
2. Every vibration speed produces its own _____.
3. A string that vibrates in only one loop produces only a single "main" tone. This is called its _____ tone.
4. A fundamental tone is the _____ pitch a vibrating object can make.
5. A string that vibrates in sections produces a fundamental tone. It also produces an _____.
6. The pitch of an overtone is _____ than the pitch of the fundamental.
7. The pitch of an overtone depends upon how many _____ vibrate.
8. Sound has *pitch* and *loudness*. Sound also has _____.
9. Quality is determined mostly by _____.
10. Different qualities are caused by different combinations of _____, _____, and _____.

MATCHING

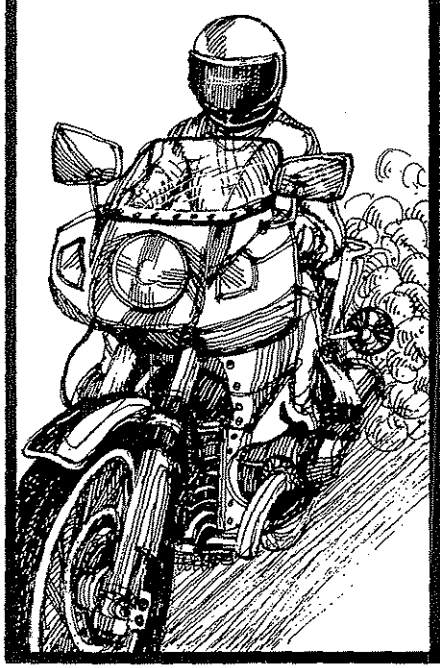
Match the two lists. Write the correct letter on the line next to each number.

1. _____ vibrating matter
2. _____ pitch, loudness, and quality
3. _____ fundamental tone
4. _____ overtone
5. _____ sound quality

a) characteristics of sound
b) higher pitched than the fundamental
c) determined greatly by overtones
d) lowest pitch of a vibrating object
e) produces sound

WHAT ARE THE DIFFERENCES BETWEEN NOISE AND MUSIC?

13



rhythm: definite and planned timing

AIM 13 | What are the differences between noise and music?

A motorcycle makes sounds. A guitar makes sounds, too. Yet the sounds are very different. Motorcycle sounds are *noise*. Guitar sounds are *music*.

What are the differences between noise and music?

You might say that it's a matter of taste. What some people think is music might be "noise" to others. But to a scientist there are differences between noise and music.

NOISE is sound that generally is not wanted. Noise can be annoying. It can also be harmful. Noise, for example, can make us tense. It can cause stomach upset.

Vibrations that produce noise do *not* follow a set pattern. They vibrate any which way. We *cannot predict* how the pattern will continue.

This is what noise might look like on an oscilloscope. Do the waves follow a regular pattern? Can you predict how the pattern will continue?

MUSIC is sound that generally is wanted. It is usually produced by instruments or voices. Music can entertain and relax us. It can create a mood.

Vibrations that produce music *follow a set pattern*. We *can predict* how the pattern will continue.

This is what a musical sound might look like on an oscilloscope. Do the waves follow a regular pattern? Can you predict how the pattern will continue?

Music has four characteristics that are not found in noise. They make the difference between noise and music.

- Music has a definite and planned *pitch*.
- Music has definite, planned timing called *rhythm*.
- Music has a definite and planned *loudness*.
- Music has a pleasant *quality*.

UNDERSTANDING NOISE AND MUSIC

Four sound-wave patterns are shown in Figures A through D. Some were made by noise. Some were made by music. Study the patterns. Answer the questions. Use figure letters in your answers.

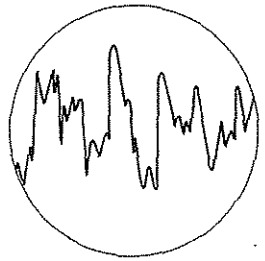


Figure A

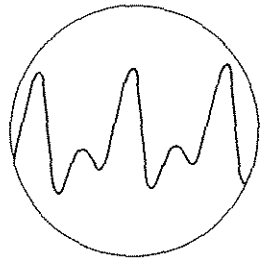


Figure B

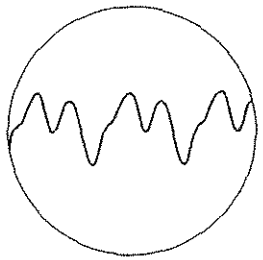


Figure C

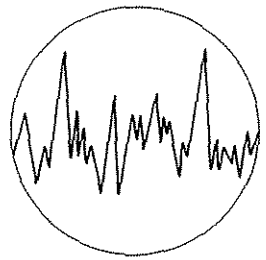


Figure D

1. Which waves were made by noise? _____
2. Which waves were made by music? _____
3. Which waves follow a definite pattern? _____
4. Which waves do *not* follow a definite pattern? _____
5. The waves that follow a definite pattern were made by _____ (music, noise).
6. The waves that do *not* follow a definite pattern were made by _____ (music, noise).
7. Which of these wave patterns *can* be predicted? _____
8. Which of these wave patterns *cannot* be predicted? _____
9. The wave patterns made by *music* _____ (can, cannot) be predicted.
10. The wave patterns made by *noise* _____ (can, cannot) be predicted.

NOISE OR MUSIC?

Several sound characteristics are listed on the chart. Each characteristic describes either noise or music. Which one is it? Write your answer next to the characteristic.

	Characteristic	Noise or Music?
1.	vibrates in regular pattern	
2.	unwanted sound	
3.	no definite rhythm	
4.	wave pattern can be predicted	
5.	planned pitch	
6.	pleasant quality	
7.	no planned pitch	
8.	wanted sound	
9.	unpleasant quality	
10.	planned loudness	
11.	wave pattern cannot be predicted	
12.	no planned loudness	
13.	definite rhythm	
14.	vibrates in no regular pattern	

REACHING OUT

Some voices are soft. Some voices are loud. No matter how loud a voice may be, it still cannot carry far.

1. Name a modern invention that makes sounds louder? _____
2. Name some inventions that carry sounds over great distances? _____

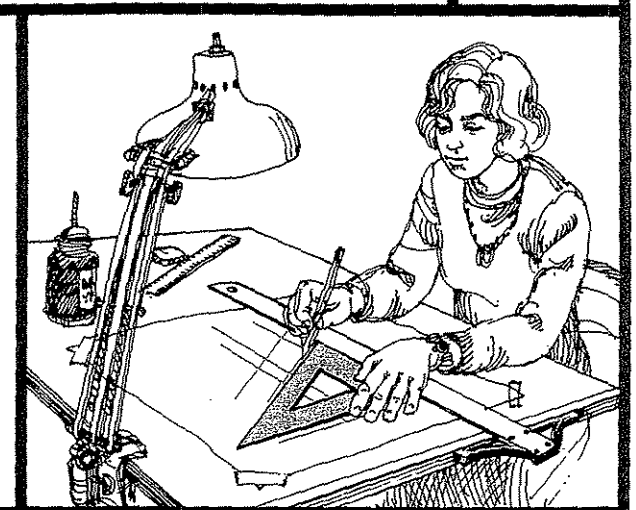
_____

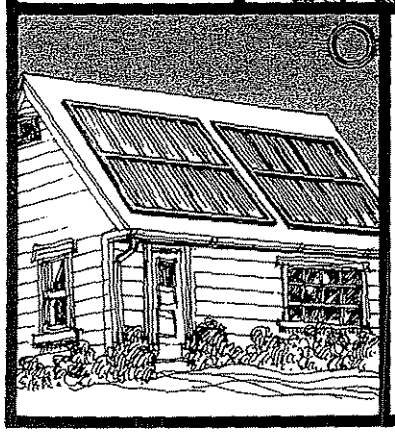
Speeches are made. Concerts are played. They are lost forever unless they are "saved."

3. Name an invention that "saves" sound? _____

HOW IS LIGHT DIFFERENT FROM SOUND?

14





right angle: a 90° angle, like any corner of a square

transverse wave: an energy wave that vibrates at right angles to its length

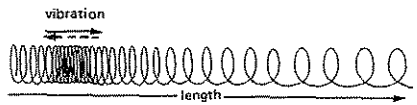
vacuum: the absence of matter

AIM 14 How is light different from sound?

Sound, you have learned, is a form of energy. It has no weight and does not take up space. But sound can do *work*. It can make things move. That is why sound is a form of energy. Energy is *the ability to make things move.*

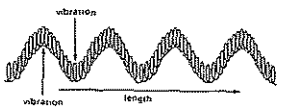
Light is a form of energy, too. But light is different from sound in many ways. How are light and sound different?

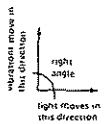
1. Sound waves are *longitudinal* waves. A longitudinal wave vibrates in the *same* direction as its length. This is what a longitudinal wave looks like. (Remember Aim 4?)



Light waves are *transverse* [trans VURS] waves. A transverse wave vibrates at *right angles* to its length. (A right angle looks like this: ⊾ .)

This is what a transverse wave looks like.





2. Sound waves move only through a *medium*. That is a solid, liquid, or gas.

Light waves do not need a medium. Light waves can move through a *vacuum*. There is no matter at all in a vacuum, not even air.

3. Sound waves travel through air at about 335 meters (1,100 *feet*) per second.

Light waves travel *much* faster. Light travels at a speed of about *300,000 kilometers* (186,000 miles) per second. This is the fastest speed in nature. Nothing travels faster than light.

4. Sound waves bend around corners easily. Light waves do not. Light waves travel in *straight lines*.

COMPARING SOUND AND LIGHT

Figures A and B show energy waves.

Look at the figures. Then answer the questions.

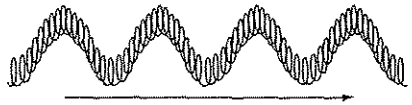


Figure A

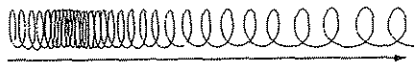


Figure B

Answer with the figure letter.

1. Which wave vibrates in the *same direction* as its length? _____
2. Which wave vibrates at right angles to its length? _____
3. Which figure shows a *sound* wave? _____
4. Which figure shows a *light* wave? _____

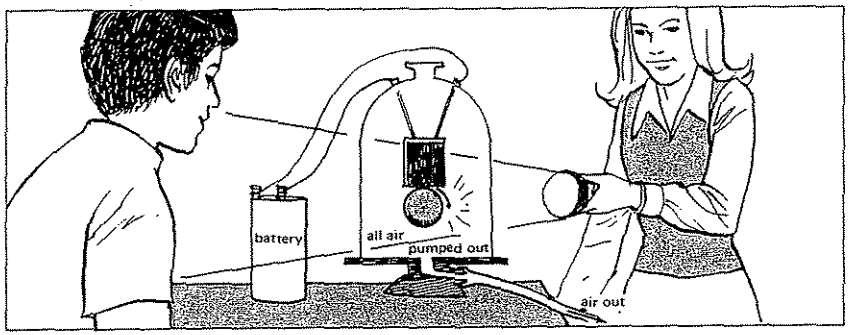


Figure C

Now look at Figure C.

5. Is there air in the jar? _____
6. What word describes the "*absence* of air"? _____
7. a) Do the students hear the bell ringing? _____

   b) Why? _____
8. If the flashlight is switched on, the light _____ pass through the jar.
   will, will not
9. Does light pass through a vacuum? _____
10. Which needs a *medium* in order to travel, sound or light? _____

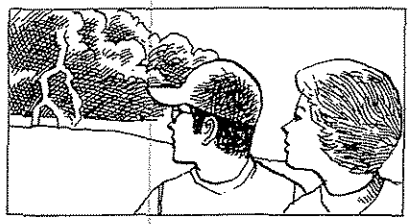


Figure D

There is a lightning and thunder storm a distance away.

Lightning and thunder happen at the same time. But you do not experience them at the same time.

11. Which of the following is correct? Circle the letter of your answer.

    a) You hear thunder before you see the lightning.

    b) You see lightning before you hear the thunder.

12. a) How fast does sound travel through air? _____

    b) How fast does light travel? _____

13. Try to figure out this one.

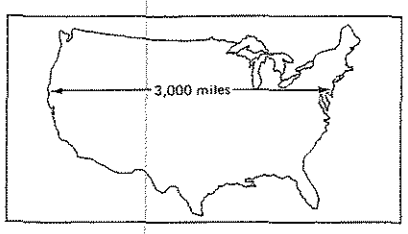


Figure E

The United States is about 3,000 miles across.

Light travels about 186,000 miles per second.

How many times can light travel across the United States in just one second? _____

14. How many round trips could light make across the United States in one second?

    _____

15. Look at Figure F.

    a) Will the girl hear her classmate calling? _____

    b) This shows that sound _____ move around corners.
    does, does not

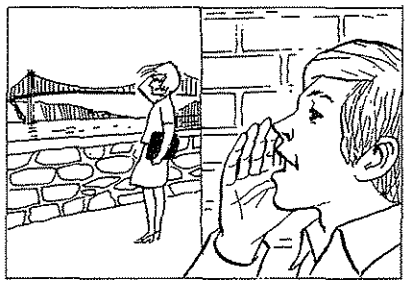


Figure F

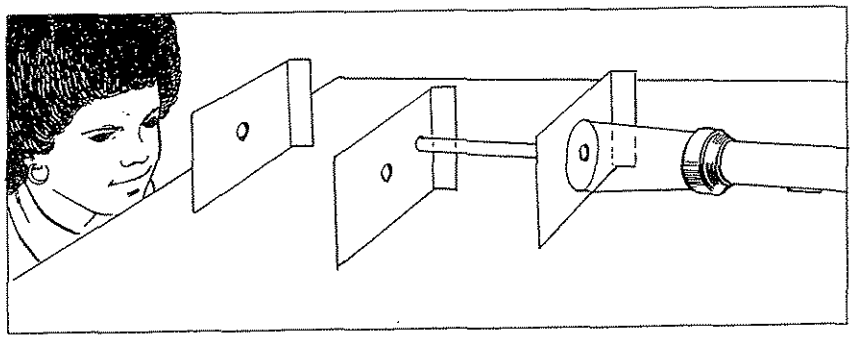


Figure G

16. Each piece of cardboard has one hole. Are the holes in a straight line? _____

17. Does the girl see the flashlight bulb? _____

18. This shows that light _____ move around corners.
    does, does not

19. Without moving her head, what can the girl do to see the light? _____

    _____

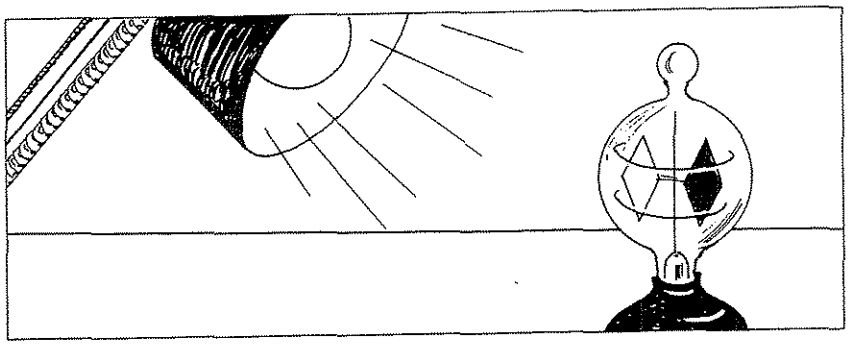


Figure H

Figure H shows a *radiometer*. The light from the bulb is turning the blades.

20. How can you stop the blades from turning? _____

    _____

21. What is the definition of energy? _____

    _____

22. Why are sound and light forms of energy? _____

SOUND OR LIGHT?

Several characteristics are listed on the chart. Each one belongs to either sound or light. Which one is it? Write either *sound* or *light* in the boxes.

	Characteristic	Belongs to *Sound* or *Light*?
1.	Moves about 335 meters per second	
2.	Transverse waves	
3.	Moves around corners	
4.	Moves only in a medium	
5.	Moves about 300,000 kilometers per second	
6.	Longitudinal waves	
7.	Does not move around corners; moves in a straight line	
8.	Moves in a vacuum	

REACHING OUT

1. Outer space contains very little matter. It is like a vacuum. How do we know that light can travel through a vacuum? _____

2. Another form of energy that you know travels at the speed of light. We use this energy in our daily lives. What is this form of energy? _____

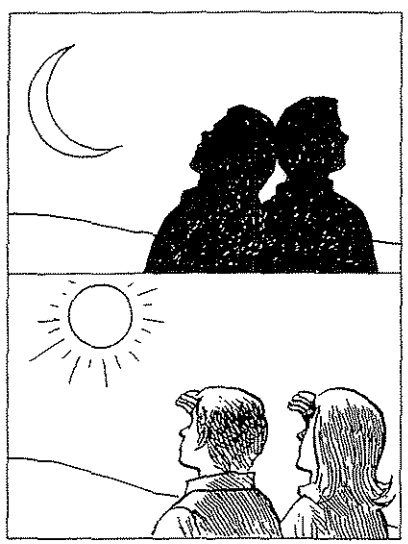
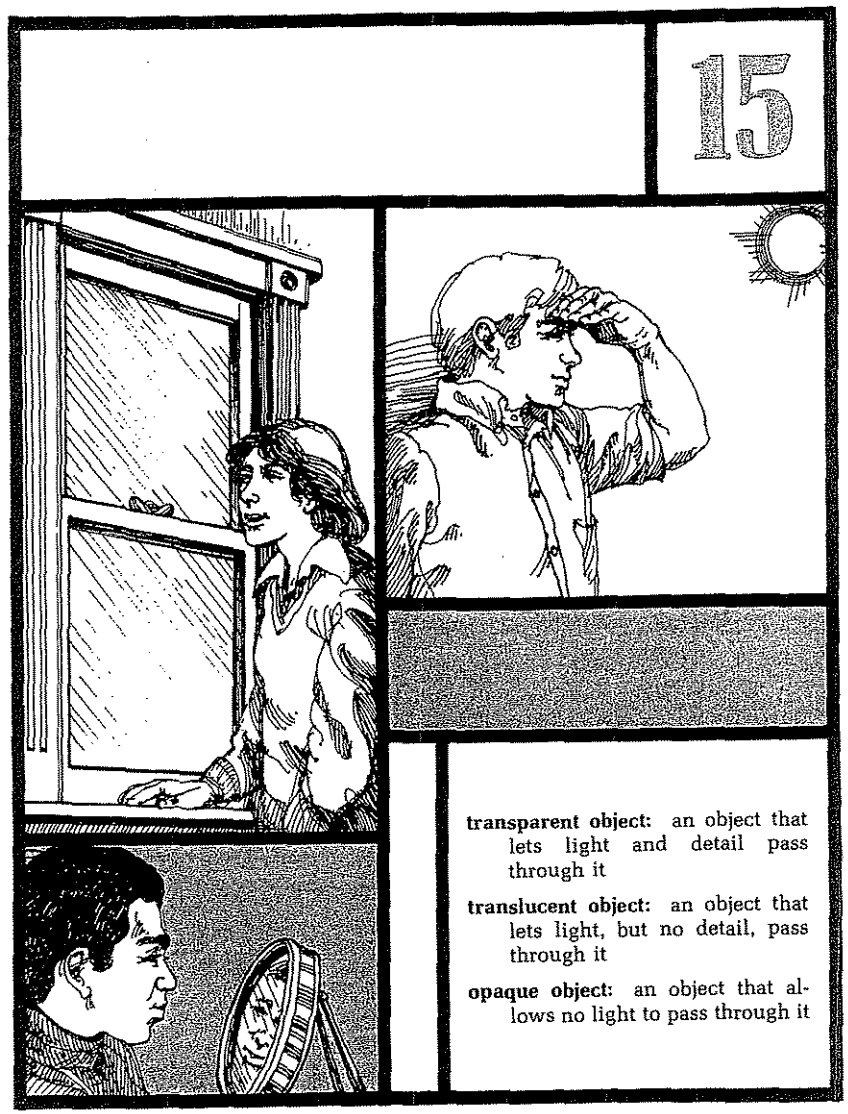


Figure I

WHAT HAPPENS TO LIGHT WHEN IT STRIKES MATTER?



transparent object: an object that lets light and detail pass through it

translucent object: an object that lets light, but no detail, pass through it

opaque object: an object that allows no light to pass through it

AIM 15 | What happens to light when it strikes matter?

Light, you have learned, travels in a straight line. It moves along at 300,000 kilometers per second. This is an almost unbelievable speed.

Light also needs no medium in order to travel. Light can move through a vacuum, where there is no matter.

What happens to light when it strikes matter? Three things can happen. The light can be *absorbed*, *reflected*, or *transmitted*.

- Light that is *absorbed* is "soaked in" by the matter it strikes.

Some objects absorb light better than others. Black objects are the best for absorbing light. In fact, black substances absorb *all* the light that strikes them.

- Light that is *reflected* "bounces off" the substance it strikes.

A mirror works by reflection. Light strikes an object. The light reflects off the object onto the mirror. The light then reflects off the mirror and into your eyes.

- Light that is *transmitted* passes through the matter it strikes.

Only certain substances transmit light. Substances that transmit light are said to be *transparent* [tranz PAIR ent]. Window glass, water, and air are transparent. We can see through them clearly.

Some substances—like waxed paper and frosted glass—transmit light. But they also "scatter" the light. We can see light through them but we cannot see any details. Such substances are said to be *translucent* [tranz LOO sent].

Substances like wood and metal do not transmit light. We cannot see through them at all. They are said to be *opaque* [oh PAYK].

HOW LIGHT STRIKES MATTER

Look at Figures A through F. Each one shows light being *absorbed*, or *reflected*, or *transmitted*. Which does each show? Answer by writing a sentence under each figure. Start the sentence with "Light is being . . ."

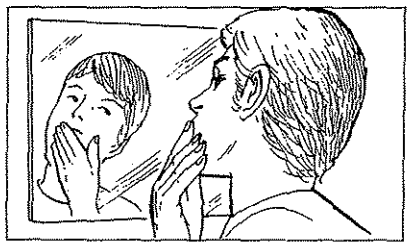


Figure A

1. _____

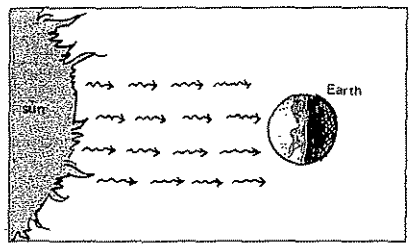


Figure B

2. _____

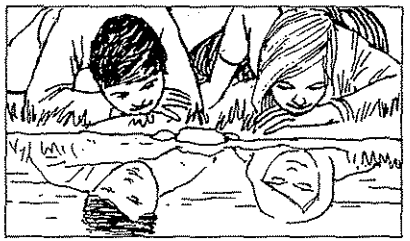


Figure C

3. _____

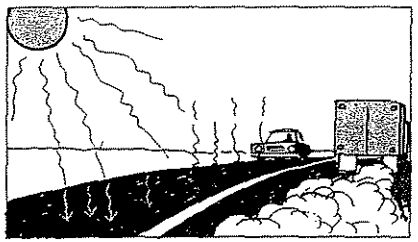


Figure D

4. _____

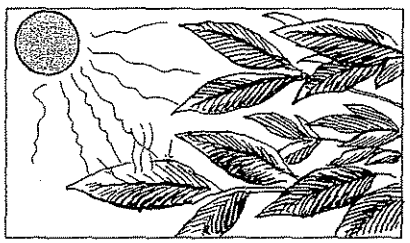


Figure E

5. _____

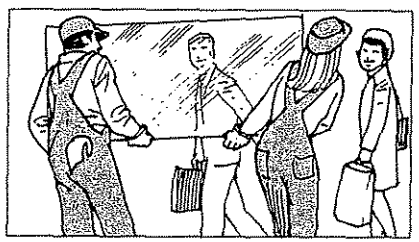


Figure F

6. _____

Now answer these questions.

7. Light that bounces off a substance is _____.
transmitted, reflected, absorbed

8. Light that passes through a substance is _____.
transmitted, reflected, absorbed

9. Light that is "soaked in" by a substance is _____.
transmitted, reflected, absorbed

TRANSPARENT, TRANSLUCENT, OR OPAQUE?

Look at Figures G, H, and I.

Each one shows an object that is either *transparent*, *translucent*, or *opaque*. Which is which? Write the correct term under each figure.

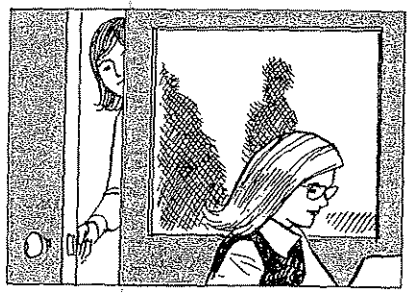


Figure G

1. _____

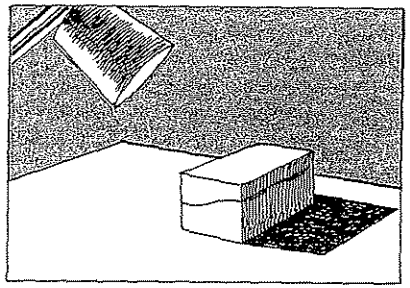


Figure H

2. _____

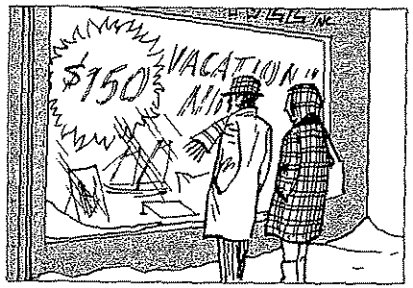


Figure I

3. _____

Now answer these questions.

4. Matter that blocks light is said to be _____.

5. Matter that transmits light but *no detail* of that light is said to be _____.

6. Matter that transmits light *along with detail* of that light is said to be

_____.

COMPLETING SENTENCES

Complete the sentences with the choices below. Three of these may be used twice.

transparent	transmitted	opaque
a desk	frosted glass	window glass
absorbed	translucent	reflected

1. Three things can happen to light when it hits matter. It can be _____,

or _____, or _____.

2. Light that is soaked in is _____.

3. Light that bounces off matter is _____.

4. Light that passes through matter is _____.

5. A substance that transmits light as well as detail is said to be _____.

6. A substance that blocks light is said to be _____.

7. A substance that transmits light but *no detail* of that light is said to be

_____.

8. An example of a *transparent* object is _____.

9. An example of an *opaque* object is _____.

10. An example of a *translucent* object is _____.

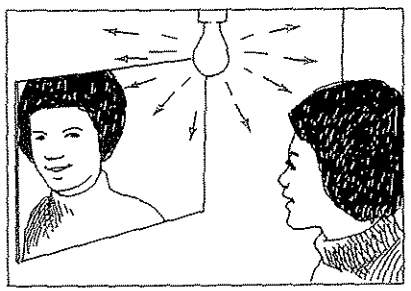


Figure J

REACHING OUT

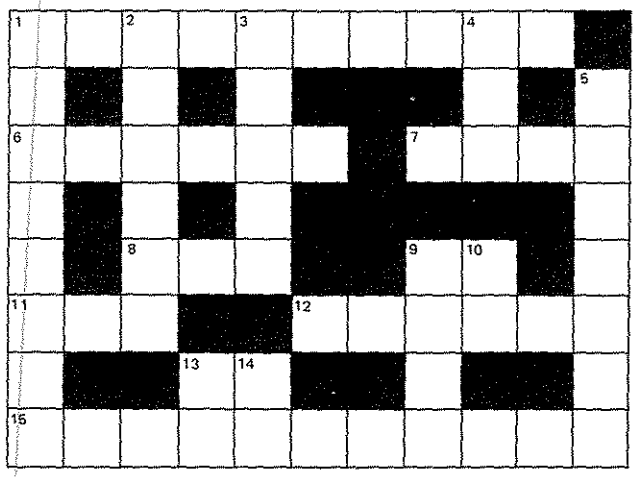
The girl in Figure J is looking at a mirror. She is seeing a reflection of herself.

Trace the path light takes in order for the girl to see herself. Use lines with arrows.

(*Hint:* You need three lines.)

CROSSWORD PUZZLE

Fill in the blank spaces by following the clues across and down.



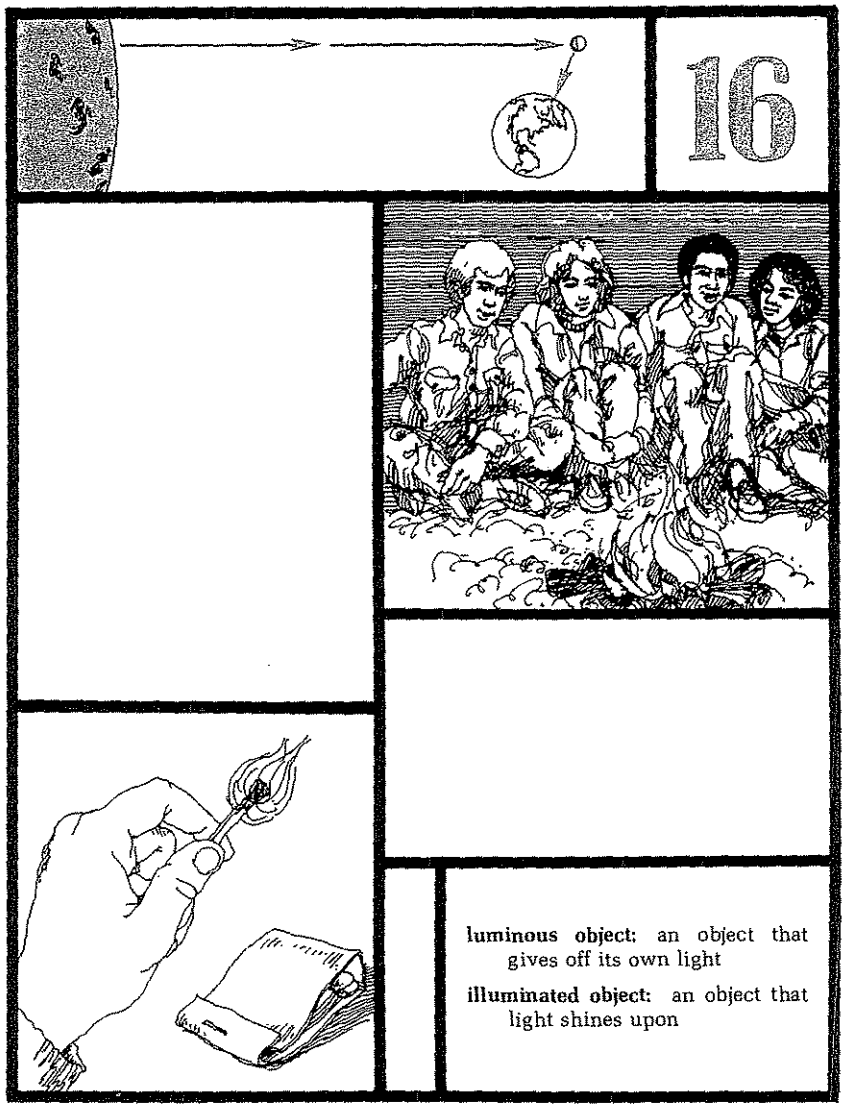
Across

1. Light travels as this kind of wave
6. What you give to a question
7. Longitudinal or transverse
8. Color of fire
9. Greeting
11. Crowd
12. Allowing no light to pass through
13. Opposite of down
15. Allowing light and detail to pass through

Down

1. An object may absorb, reflect, or ____ light
2. Soak in
3. 300,000 kilometers per second is the ____ of light
4. Ocean
5. Bounce off
9. Natural covering on your head
10. A kind of intelligence test
13. United Nations
14. Extra message in a letter

WHERE DOES LIGHT COME FROM?



AIM 16 | Where does light come from?

The sun gives off light. So does the moon. But they do not give off light in the same way.

The sun gives off its *own* light. The moon does not. The moon has no light of its own. The moon gets its light *from* the sun. Sunlight shines upon the moon. The light then is reflected. Some of the reflected light reaches Earth.

▪ An object that gives off its own light is called a *luminous* [LOO min us] object. The sun is a luminous object. So are switched-on light bulbs and burning wood.

▪ An object that light shines *upon* is called an illuminated [ill OO min AY ted] object. The moon is an illuminated object. In fact, most things you see are illuminated objects. They do not give off their own light. Light shines *upon them*.

Look around. How many different things do you see? How many give off their own light? How many just *receive* light?

Look at this book, for example. Does it give off its own light, or does light just shine upon it? Is this book *luminous* or *illuminated*?

Some luminous objects are very small. Their light seems to come from a *single point*. It does not spread out much.

A small luminous body is called a *point* source of light.

Some luminous objects are large—and close by. Their light comes from *many* different points. The light spreads out greatly. This kind of luminous body is called an *extended* light source.

LUMINOUS AND ILLUMINATED OBJECTS

Figure A

Study Figure A. Then answer the questions.

1. The _____ (flashlight, cat) gives off its own light.
2. The _____ (flashlight, cat) does not give off its own light.
3. The _____ (cat, flashlight) is illuminated.
4. The _____ (cat, flashlight) is luminous.
5. A *luminous* body _____ (does, does not) give off its own light.
6. An *illuminated* body _____ (does, does not) give off its own light.
7. Complete this sentence: _____ (An illuminated, A luminous) body usually gets its light from _____ (an illuminated, a luminous) body.

POINT AND EXTENDED LIGHT SOURCES

Study Figures B and C. Answer the questions by figure *letter*.

One of these diagrams shows a *point* light source. The other shows an *extended* light source.

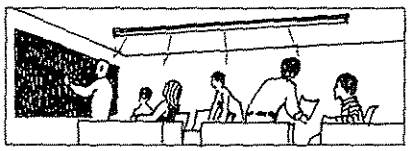


Figure B

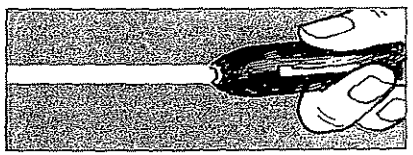


Figure C

1. Which is the *point* light source? _____
2. Which is the *extended* light source? _____
3. Which light *spreads out* greatly? _____
4. Which light does *not* spread out much? _____
5. Which light seems to come from *one* point? _____

6. Which light comes from *many* points? _____

7. Which would you use to light up a *large* area? _____

8. Which would you use to light up a *small* area? _____

9. Which light is more concentrated? _____

10. Which light is *less* concentrated? _____

COMPLETING SENTENCES

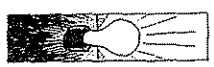
Complete the sentences with the choices below. Four of these may be used twice.

a point	an extended	a luminous
an illuminated	burns	illuminated

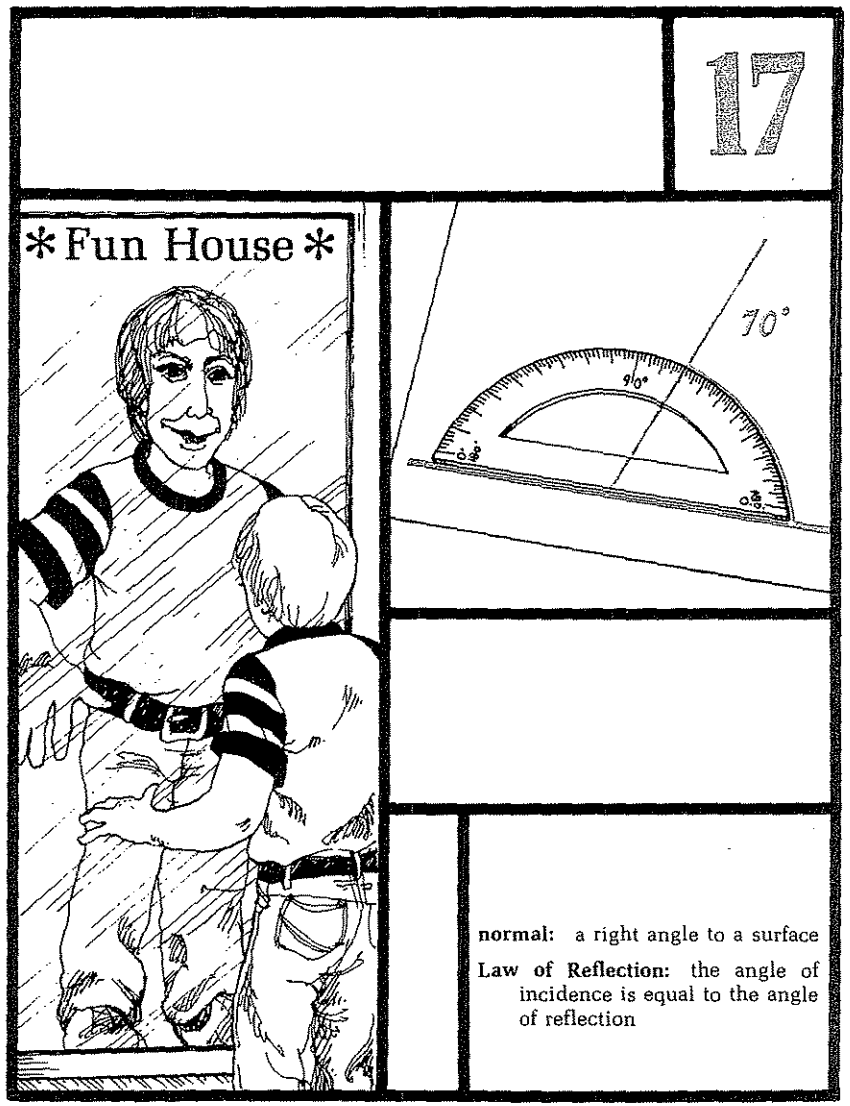
1. An object that gives off its own light is called _____ object.
2. An object that *receives* light is called _____ object.
3. A flaming log is an example of _____ object.
4. You are an example of _____ object.
5. Most objects we see are _____ objects.
6. Any object becomes luminous when it _____.
7. A small luminous object is called _____ source of light.
8. A large and close luminous object is called _____ source of light.
9. Light from _____ light source does not spread out.
10. Light from _____ light source spreads out.

MATCHING

Match the two lists. Write the correct letter on the line next to each number.

1. _____ light		a) an *extended* light source
2. _____ luminous object		b) receives light
3. _____ illuminated object		c) gives off its own light
4. _____		d) a *point* light source
5. _____		e) a form of energy

HOW DOES LIGHT REFLECT?

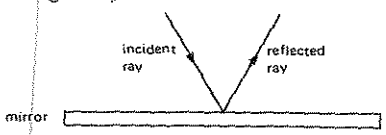


AIM 17 | How does light reflect?

How does a ball bounce back to you after you throw it against a wall? It depends upon how you throw it. If you throw the ball straight on, it will bounce back straight on. If you throw it at an angle, it will bounce back at an angle.

Light, you know, can bounce. "Bounced" light is *reflected* light. We can predict how reflected light will behave. Just follow the explanation.

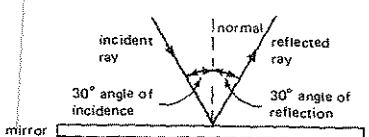
A single beam of light is called a *light ray*. Light is made up of many, many light rays. But let us look at *one* light ray.



This is a single light ray. It is hitting a flat mirror at an angle. Then it is bouncing off. It is *reflecting*.

The ray that *hits* the mirror is called the *incident* [IN si dent] ray.

The ray that *bounces off* the mirror is called the *reflected* ray.



Now let's draw a line that makes a *right angle* (90 degrees) where the incident ray hits the mirror. This line is called the *normal*.

- The angle between the incident ray and the normal is called the *angle of incidence*.
- The angle between the reflected ray and the normal is called the *angle of reflection*.

The *Law of Reflection* states that "the angle of incidence is equal to the angle of reflection."

In the example on this page, the angle of incidence is 30 degrees. The angle of reflection, then, is *also* 30 degrees.

REFLECTING RAYS

Two reflecting rays are shown in Figures A and B. Identify the parts shown by number. Choose from the following:

incident ray	normal
reflected ray	angle of incidence
	angle of reflection

Write your answers next to the correct numbers.

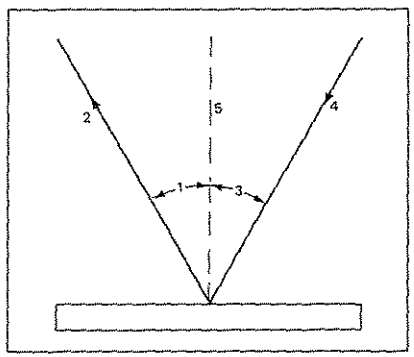


Figure A

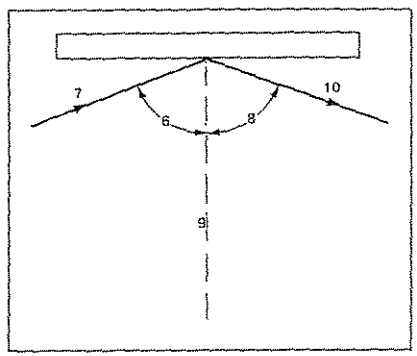


Figure B

1. _____
2. _____
3. _____
4. _____
5. _____

6. _____
7. _____
8. _____
9. _____
10. _____

11. State the Law of Reflection. _____

_____

12. Which of the angles above are equal? (Use numbers.)

a) In Figure A, _____ and _____ are equal.

b) In Figure B, _____ and _____ are equal.

Something Extra

If you have a protractor, measure the angles in Figures A and B. What degrees do the angles measure? Figure A _____

Figure B _____

KINDS OF REFLECTIONS

There are two kinds of reflections: regular and *diffuse* [di FYOOS]. What are the differences? Find out for yourself. It's easy! Figures C and D show the two kinds of reflection. Study each figure. Then answer the questions that go with each.

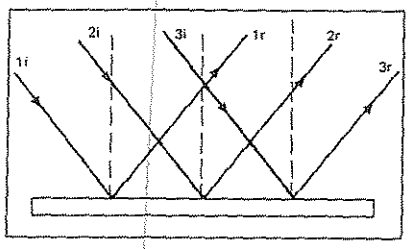


Figure C *Regular reflection*

1. Figure C shows _____ reflection. (regular, diffuse)
2. A surface that gives a regular reflection is _____. (even, uneven)
3. Every ray has its own normal. In regular reflection, the normals _____ face in the same direction. (do, do not)
4. In a regular reflection . . .
   a) every angle of incidence _____ the same. (is, is not)
   b) every angle of reflection _____ the same. (is, is not)

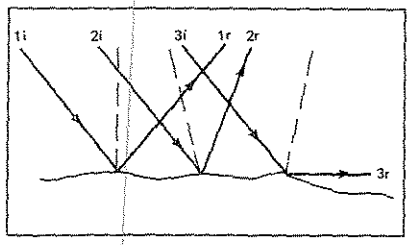


Figure D *Diffuse reflection*

5. Figure D shows a _____ reflection. (regular, diffuse)
6. A surface that gives a diffuse reflection is _____. (even, uneven)
7. In a diffuse reflection, the normals _____ face in the same direction. (do, do not)
8. In a diffuse reflection . . .
   a) every angle of incidence _____ the same. (Careful, remember where the angle of incidence is!) (is, is not)
   b) every angle of reflection _____ the same. (is, is not)

What do you think?

9. Which kind of reflection do you think a mirror gives, regular or *diffuse*?

   _____

10. Hold your book up and look at this page.
    a) Does the page reflect like a mirror? _____
    b) This shows that paper gives a _____ reflection. (regular, diffuse)
11. Run your hand over this page. To your sense of touch, paper is _____. (rough, smooth)
12. a) To your senses, the surface of the paper is _____. (even, uneven)
    b) To light, the surface of the paper is _____. (even, uneven)

COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

incident	diffuse	angle of incidence
equal	angle of reflection	ray
normal	reflected	regular

1. A single line of light energy is called a _____.
2. A ray that strikes a surface is called an _____ ray.
3. A "bounced" ray is called a _____ ray.
4. A line that makes a 90° angle to a surface is called a _____.
5. The angle between an incident ray and its normal is called the _____.
6. The angle between a reflected ray and its normal is called the _____.
7. An angle of incidence is _____ to its angle of reflection.
8. There are two kinds of reflections. They are _____ and _____.
9. A perfectly even surface gives a _____ reflection.
10. An uneven surface gives a _____ reflection.

KEEPING UP WITH SCIENCE

THE STRANGE CASE OF THE SPEEDING HOUSE

In 1979, the Florida highway police starting checking their radar units. There had been many complaints by angry drivers who had been given fines for speeding. They insisted they were travelling *within* the speed limit.

The first few test readouts seemed normal and accurate. But then, several weird ones showed up. One radar unit indicated that a tree and a house were moving along the highway. The tree, according to the radar, was doing 28 miles per hour—and the house was speeding along at 86 miles per hour. This unit had "goofed", and so had many others.

Until these tests, radar evidence was accepted as fact. To understand why, let's see how radar works.

Speed-check radar sends out a continuous stream of radio waves. They vibrate at a certain *frequency*. That is, the waves vibrate a certain number of times a second. If the waves strike an object, the waves reflect (bounce back). A soundless "echo" is produced.

If the radio waves strike an object that is *not* moving, its echo will vibrate at the same speed.

If, however, the object *is* moving, the frequency of the echo waves will be different than the outgoing wave. The faster the object is moving, the greater will be the change in frequency.

A radar unit that emits (sends out) a radio wave also receives its echo.

A speed-check radar echo is not viewed on a screen like other radar echoes are. (You have seen these screens on TV and in the movies). Instead, the echo goes to a computer. The computer measures the difference in speed between the outgoing and incoming waves. The figure is instantly changed to the speed of the moving object.

So far, so good! But there is a hitch. Radar *is* precise for measuring speed, but *only* when an object is moving in *direct line* with the radar's waves. When the object is moving at an *angle* to the waves, speed readings are not correct. Radio waves from CB sets also can cause readout errors. The error of the "86-mph house" was caused by a stray CB signal.

WHAT IS A SHADOW?

shadow: a dark area caused by blocked light

umbra: the darker part of a shadow

penumbra: the lighter part of a shadow

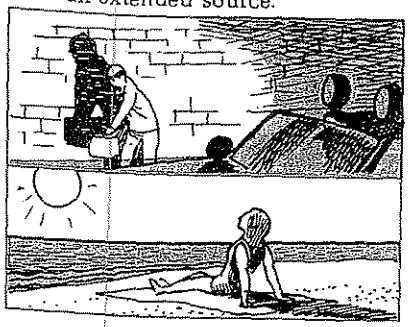
AIM 18 What is a shadow?

You are walking along the street on a sunny day. You see shadows of lampposts, fences, buildings, cars. You see your own shadow too! It follows you as you walk. It imitates everything you do. Then a cloud blocks the sun, and the shadows disappear.

What is a shadow? How is it formed?

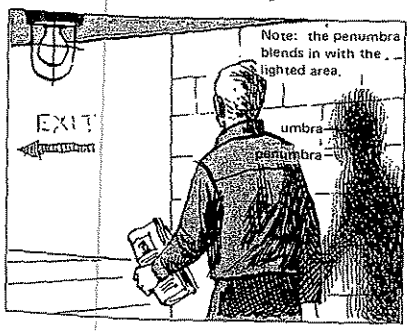
A shadow is an area of *darkness* or *partial darkness*. It forms when an object gets in the way of light. The object prevents light from striking some surface.

Blocked light may come from a *point* source or from an *extended* source.



Blocked light from a *point source* forms a completely dark shadow. This area of total darkness is called an *umbra*. There is a sharp border between an umbra and the surrounding bright area. You can see exactly where the shadow ends.

The sun is very large. But it is very far away. The sun acts like a point source of light. Objects on earth that block the sun form dark, sharp umbra shadows.



A shadow from an *extended source* has two parts: a dark inner part and a gray outer part.

- The dark inner part receives *no* light. This is the *umbra*.
- The gray outer part receives *some* light. This area is called the *penumbra* [pi NUM bruh].

UNDERSTANDING SHADOWS

Study Figures A and B. Then answer the questions.

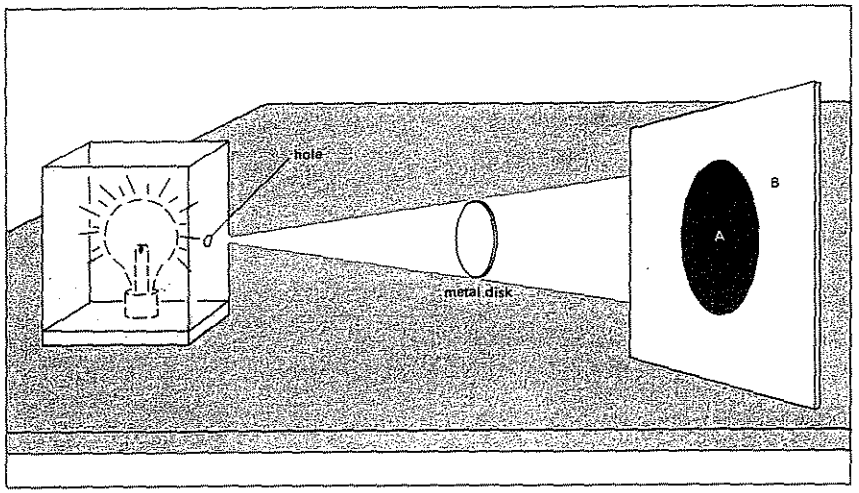


Figure A

The light bulb is covered with a hood. The hood has a hole.

1. The hole is _____ (large, small).
2. The hole makes the light bulb _____ (a point, an extended) light source.
3. a) The disk is _____ (opaque, translucent, transparent).

   b) It _____ (transmits, blocks) light.
4. A shadow _____ (is, is not) formed.
5. How many parts does this shadow have? _____
6. The shadow is labeled _____ (A, B, A and B).
7. The shadow is receiving _____ (some light, no light at all).
8. This kind of shadow is called _____ (an umbra, a penumbra).
9. Area B is _____ (partly in shadow, not in shadow at all).

10. a) The border between the shadow and the area that is not in shadow is _____.
sharp, fuzzy

b) This shows that the light source is _____.
a point, extended

11. If you remove the hood, the shadow _____ change.
will, will not

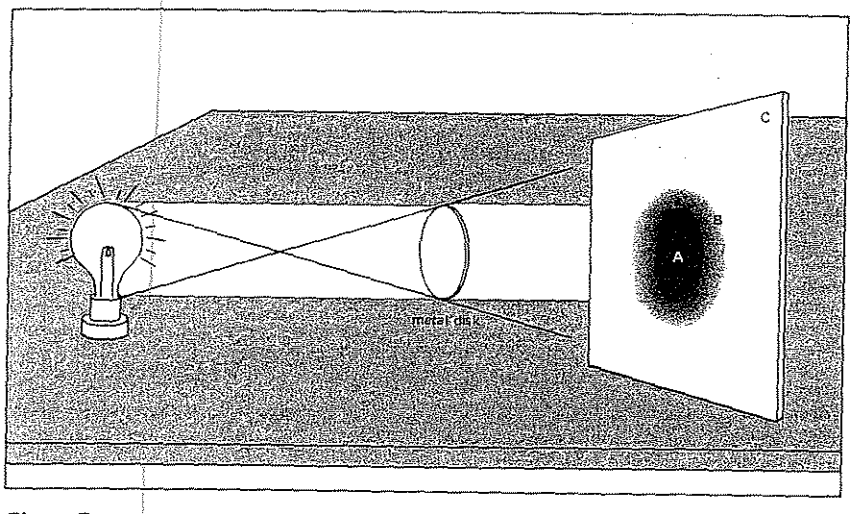


Figure B

The hood has been removed from the bulb.

12. The light source is now _____.
a point, extended

13. Is the shadow the same as in Figure A? _____

14. a) How many parts does this shadow have? _____

b) What are they labeled? _____

15. Area A is receiving _____.
no light at all, part of the light

16. What do we call the part of the shadow labeled A? _____

17. Area B is receiving _____.
no light at all, part of the light

18. What do we call the part of the shadow labeled B? _____

19. The area at C is _____ in shadow.
entirely, partly, not

20. The border between the penumbra and area C is _____.
sharp, fuzzy

21. a) The penumbra goes out of shadow _____.
suddenly, gradually

b) This shows that the light source is _____.
a point, extended

22. Which is darker, an umbra or penumbra? _____

23. Which is a gray shadow area, an umbra or penumbra? _____

COMPLETING SENTENCES

Complete the sentences with the choices below. One of these may be used three times. One of these may be used twice.

is not	darkness	blocked
penumbra	umbra	gray
sharp	gradually	partial darkness
darker	landing	

1. A shadow is an area of _____ or _____.
two words

2. A shadow is formed when light is _____. The light is stopped from _____ on a surface.

3. The part of a shadow that receives no light at all is called the _____.

4. The part of a shadow that receives some light is called the _____.

5. A point light source gives a shadow that has only an _____.

6. An extended light source gives a shadow that has an _____ and a _____.

7. An umbra is _____ than a penumbra.

8. A penumbra can be described as the _____ area of a shadow.
one word

9. The border of a shadow from a point light source is _____.

10. The border of a shadow from an extended light source _____ sharp. It changes _____.

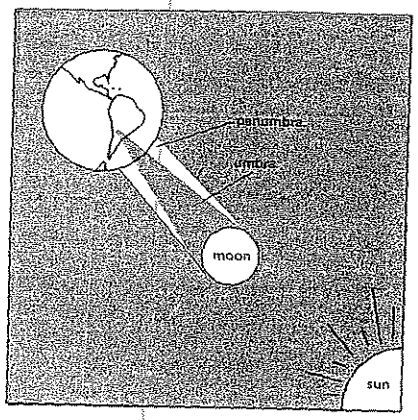


Figure C

At times, the shadow of the moon hits the earth's surface. Parts of the earth become totally dark. Other parts become partly dark. What is this "show of nature" called? _____

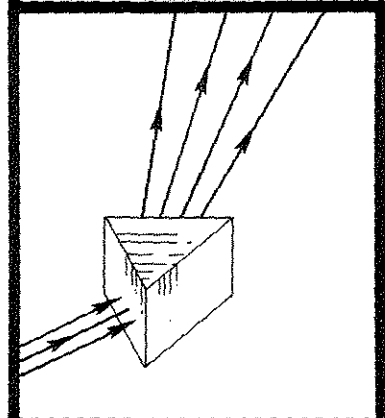
WORD SEARCH The words in this list are hidden within the group of letters in the box. Try to find each word. When you find it, draw a line around the word. The spelling may go in any direction.

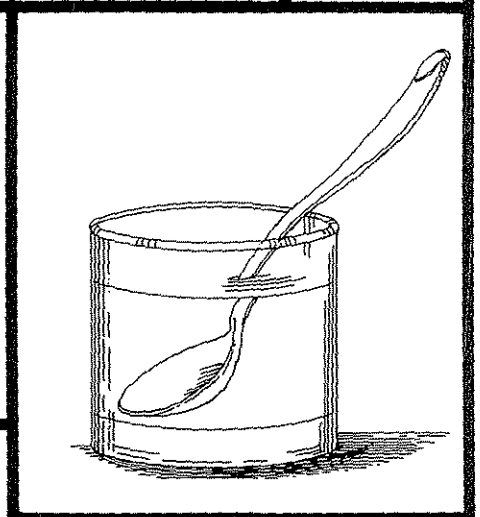
ILLUMINATED
LUMINOUS
POINT
EXTENDED
NORMAL
INCIDENCE
REFLECTION
RAY
SHADOW
UMBRA
PENUMBRA

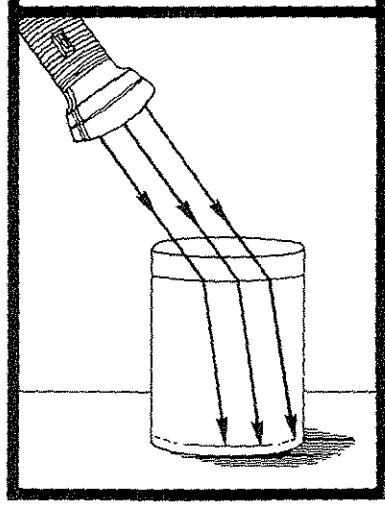
N	O	L	A	M	R	O	N	O	R	D
A	R	A	U	L	U	P	E	N	E	N
E	B	A	D	M	P	O	X	T	D	O
C	L	H	Y	T	I	I	A	U	M	I
N	U	E	X	T	E	N	D	E	D	T
E	M	T	E	N	I	T	O	I	B	C
D	I	N	O	M	A	L	V	U	X	E
I	M	R	U	C	I	D	E	M	S	L
C	U	L	U	M	I	R	I	B	D	F
N	L	W	O	D	A	H	S	R	S	E
I	P	E	N	U	M	B	R	A	N	R

WHAT IS REFRACTION?

19







refraction: the bending of light as it passes at an angle from one medium to another

AIM 19 What is refraction?

Light travels in straight lines. But light rays can also "bend." They can *change direction.*

You have seen that light changes direction when it is reflected. Light also changes direction when it passes *at an angle* from one medium into another medium. This bending is called *refraction* [ree FRAK shun].

Refraction causes us to see objects at positions different from their actual positions. You may have experienced refraction. Did you ever reach into a fish tank to pick up a rock? Was the rock exactly where you thought it was?

How can refraction be explained?

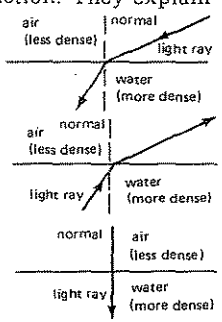
Light travels at different speeds through different mediums. Light travels at about 300,000 kilometers (186,000 miles) per second in air. But light slows down in other substances. In water, for example, light slows down to about 225,000 kilometers (140,000 miles) per second.

The speed at which light travels through a medium depends upon the *density* of that medium. Density has to do with how closely packed the molecules of a substance are. The more closely packed the molecules are, the *more dense* the substance is.

Different substances have different densities. For example water is more dense than air.

The following are the *Laws of Refraction*. They explain how light "bends."

- Light that moves at an angle from a less dense medium to a more dense medium bends *towards* the normal.
- Light that moves at an angle from a more dense medium to a less dense medium bends *away from* the normal.
- Light that moves straight on from one medium to another does not bend. It is not refracted.



UNDERSTANDING REFRACTION

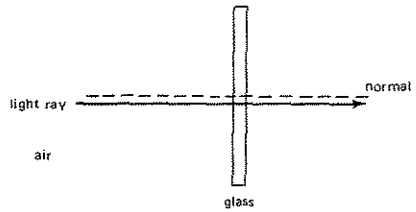


Figure A

1. From your own experience, you know that glass is _____ (more, less) dense than air.
2. In Figure A, light is passing from _____ (glass to air, air to glass).
3. The light is hitting the glass _____ (at an angle, straight on).
4. The light _____ (is, is not) bending. It _____ (is, is not) being refracted.
5. Why isn't the light being refracted? _____
6. Write the part of the Law of Refraction that explains why this is happening. _____

Look at Figures B through G. In each, light is being refracted. The dotted line in color is the normal. Is the light being refracted *towards* the normal or *away from* the normal? Complete the sentence under each figure.

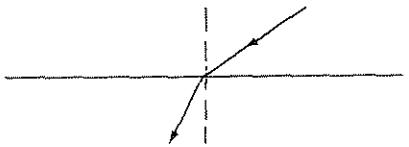


Figure B

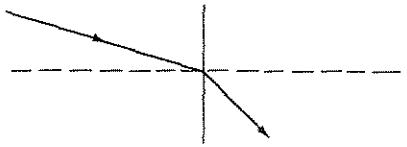


Figure C

7. Light is being refracted _____ (towards, away from) the normal.

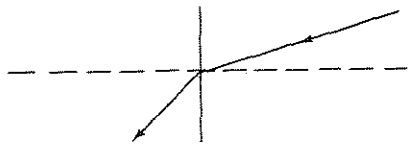


Figure D

8. Light is being refracted _____ (towards, away from) the normal.

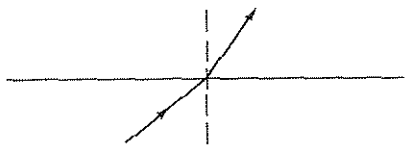


Figure E

9. Light is being _____
10. Light _____

Now, answer with complete sentences.

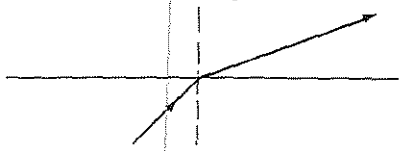


Figure F

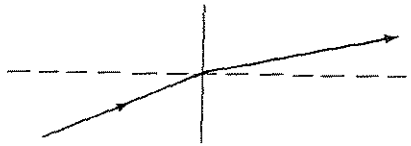


Figure G

11. _____

_____

12. _____

_____

WHAT'S HAPPENING?

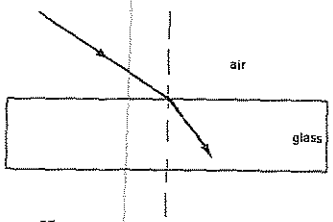


Figure H

Look at Figures H and I. Answer the questions with each.

1. a) In Figure H, light is passing from _____ (air to glass, glass to air).

   b) Glass is _____ (more, less) dense than air.

2. The light is hitting the glass _____ (at an angle, straight on).

3. The light _____ (is, is not) bending. It _____ (is, is not) being refracted.

4. The light is being refracted _____ (towards, away from) the normal.

5. Write the part of the Law of Refraction that explains why this is happening.

_____

_____

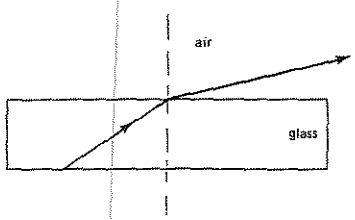


Figure I

6. a) In Figure I, light is passing from _____ (air to glass, glass to air).

   b) Air is _____ (more, less) dense than glass.

7. The light is hitting the air _____ (at an angle, straight on).

8. The light _____ (is, is not) bending. It _____ (is, is not) being refracted.

9. The light is being refracted _____ (towards, away from) the normal.

10. Write the part of the Law of Refraction that explains why this is happening.

_____

_____

REFRACTION AND CHANGE OF POSITION

Study Figure J. Answer the questions.

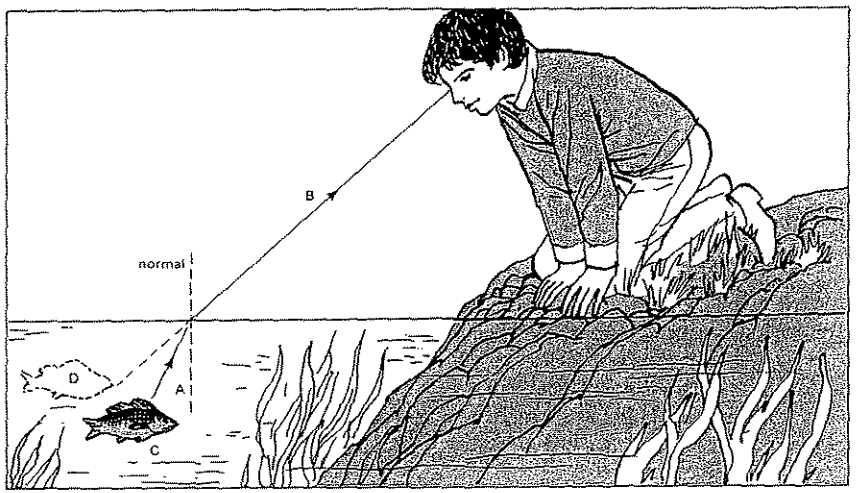


Figure J

The fish is actually at C. But to the boy, the fish *appears* to be at D.

1. The boy sees the fish because light is traveling _____ (from the boy's eyes to the fish, from the fish to the boy's eyes).

2. The fish is _____ (giving off its own light, reflecting light).

3. The light is moving from _____ (water to air, air to water).

4. The light from the fish is being refracted _____ (towards, away from) the normal.

5. The boy sees the fish in line with the refracted light. The refracted light is

_____.
A, B

6. a) The boy sees the fish _____ than it really is.
farther away, closer

b) The boy also sees the fish _____ in the water than it really is.
higher, lower

7. Refraction _____ seem to change the position of an object.
does, does not

COMPLETING SENTENCES

Complete the sentences with the choices below. One of these may be used twice.

is not	refraction	more slowly
away from	more	air
at an angle	towards	less

1. The bending of light as it passes from one medium to another is called

_____.

2. Refraction takes place when light strikes a surface _____ to the normal.

3. Light that strikes a surface in the same direction as the normal _____ refracted.

4. Light travels at about 300,000 kilometers per second in _____.

5. Glass and water are _____ dense than air.

6. Light travels _____ in glass or water than it does in air.

7. Light that moves at an angle from a less dense medium to a more dense medium is refracted _____ the normal.

8. Light that moves at an angle from a more dense medium to a less dense medium is refracted _____ the normal.

9. The light ray in Figure K is being refracted _____ the normal.

10. A is _____ dense than B.

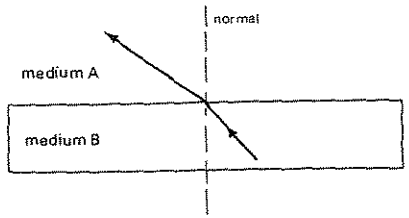


Figure K

REACHING OUT

Do this at home.

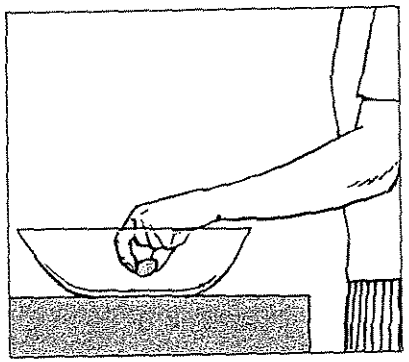


Figure L

Place a penny into a shallow bowl.

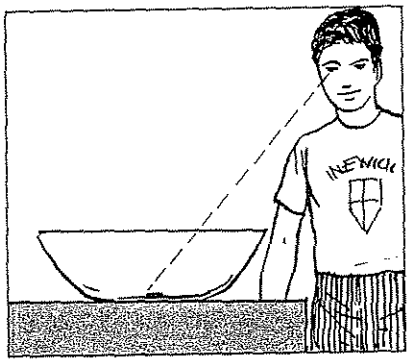


Figure M

Move back slowly. Stop when you no longer can see the penny.

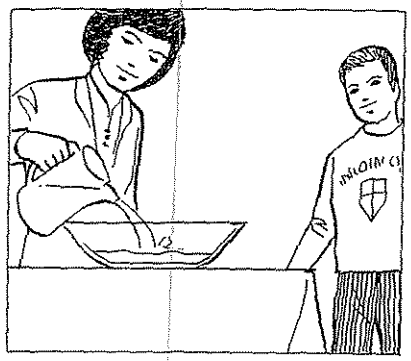


Figure N

Have a member of your family slowly pour water into the bowl. (Careful, don't move the penny.)

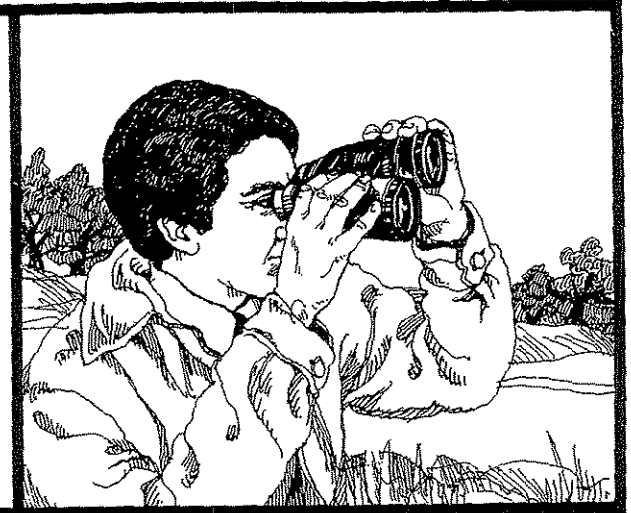
Notice what happens.

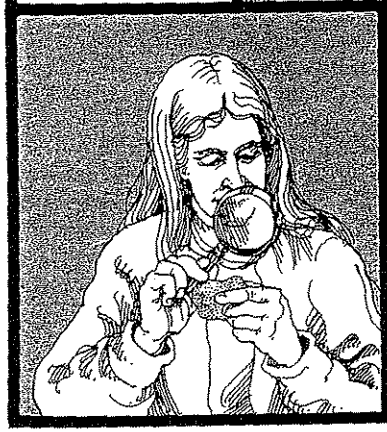
1. Write down what you see. _____

2. Try to explain why this happens. _____

WHAT IS A LENS?

20





lens: a transparent material that refracts light in a definite way

convex lens: a lens that is curved outward

concave lens: a lens that is curved inward

AIM 20 | What is a lens?

Have you ever snapped a photo or looked through a microscope? If your answer is yes, then you have used an *optical device.*

There are many kinds of optical devices. Cameras and microscopes are two examples. Others are projectors, binoculars, telescopes, and even eyeglasses.

Every optical device is different. But they all have one thing in common. Each one has at least one *lens.*

What is a lens? A lens is a transparent substance that bends or *refracts* light in a *definite* way.

Most lenses are made of glass. Many lenses are made of plastic.

Most lenses have one or two curved surfaces.

There are two main types of lenses: *convex* [kon VEKS] and *concave* [kon KAVE].

▪ A *convex* lens is thicker at the center than at the edge. It *magnifies* or makes things look *bigger.*

A convex lens *converges,* or brings together, light rays. The point where the light rays meet is called the *focal* [FOE kul] *point.*

Light that passes through a convex lens can be focused on a screen or other surface. This forms an *image* of the object that gave the light. Convex lenses are used in projectors and cameras.

▪ A *concave* lens is thinner at the center than at the edge. It *minifies* or makes things look *smaller.*

A concave lens *spreads out* light rays. They cannot form an image on a screen.

Concave lenses are often used together with convex lenses. They help the convex lenses give sharper images.

Most eyeglass lenses have combinations of concave and convex curves.

UNDERSTANDING LENSES

Six lenses are shown in Figure A. Study them. Then answer the questions by writing the correct letters.

Figure A

What You Need To Know: *Plano* means "plane" or "flat."

Which lens or lenses . . .

1. are thicker at the center than at the edge? _____
2. are thinner at the center than at the edge? _____
3. are *concave?* _____
4. are *convex?* _____
5. are *plano convex?* _____
6. are *plano concave?* _____
7. is *double concave?* _____
8. is *double convex?* _____

Which lenses . . .

9. magnify? _____
10. minify? _____
11. *refract light?* _____
12. converge light? _____
13. spread out light? _____
14. can form an image on a screen? _____
15. cannot form an image on a screen? _____
16. are most important for projectors and cameras? _____

Now look at Figure B.

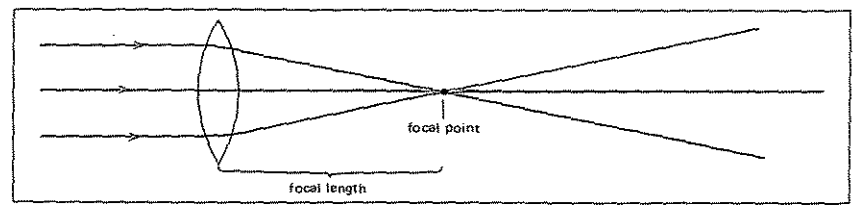


Figure B

17. a) Figure B shows a _____ lens.
    (concave, convex)

    b) It _____ light rays.
    (converges, spreads)

18. What do we call the point where light rays converge? _____

19. What do we call the distance between a lens and its focal point? _____

ABOUT FOCAL LENGTH

Different lenses have different focal lengths.

Focal length depends upon the strength of a lens.

- The stronger the lens, the shorter the focal length.
- The weaker the lens, the longer the focal length.

A strong lens has a deeper curve than a weak lens.

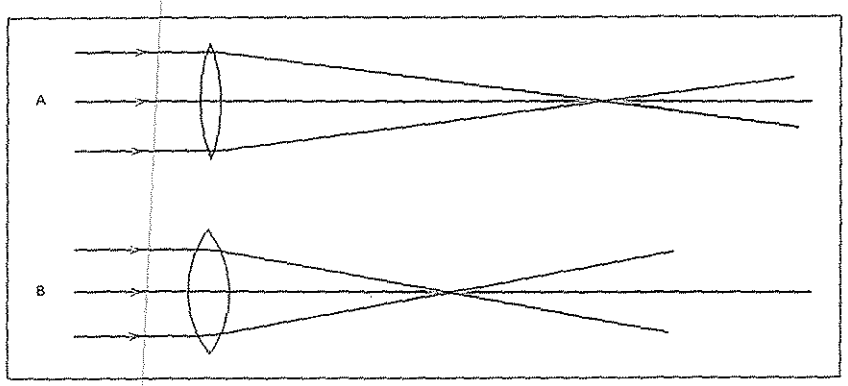


Figure C

Two converging lenses are shown in Figure C. Study the figure. Then answer the questions by writing the correct letters.

Which lens . . .

1. is more curved? _____
2. is less curved? _____
3. is stronger? _____
4. is weaker? _____
5. refracts light less? _____
6. refracts light more? _____
7. has the shorter focal length? _____
8. has the longer focal length? _____
9. magnifies more? _____
10. magnifies less? _____

Now look at Figure D.

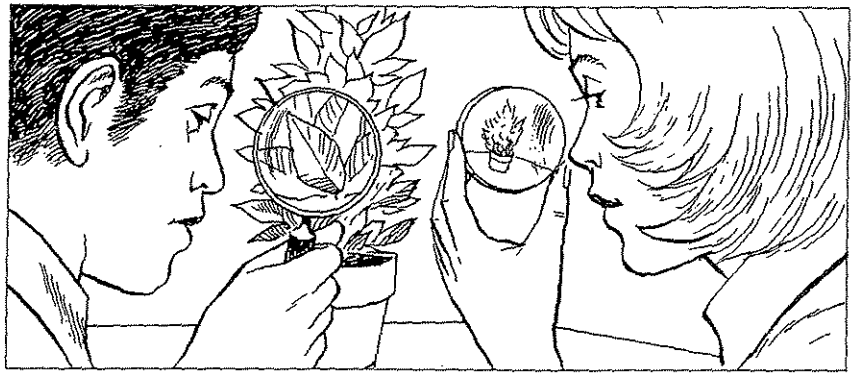


Figure D

11. What kind of lens is the boy holding? _____
12. What kind of lens is the girl holding? _____

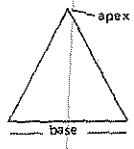
COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

refracts	smaller	center
focal length	concave	convex
edge	focal point	larger

1. A lens is a transparent material that _____ light in a definite way.
2. The two main types of lenses are _____ and _____ lenses.
3. A concave lens makes things look _____.
4. A convex lens makes things look _____.
5. The thickest part of a convex lens is its _____.
6. The thickest part of a concave lens is its _____.
7. A _____ lens can form an image on a screen.
8. A _____ lens cannot form an image on a screen.
9. The point where converging light meets is called the _____.
10. The distance between a lens and its focal point is called its _____.

REACHING OUT



A prism is shaped like a wedge.

Its point is called the *apex*. The opposite flat surface is called the *base*.

Lenses can be described as combinations of prisms.

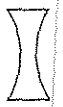
One kind of lens can be described as a combination of prisms touching at their apexes.

Another kind of lens can be described as a combination of prisms touching at their bases.

1.

   How would you describe a *convex* lens? _____

   _____

2. 

   How would you describe a *concave* lens? _____

   _____

SPELL THE MISSING WORD

Fill in the missing letters to spell the terms that fit the definitions.

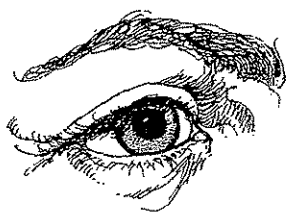
When you have answered correctly, you will spell another term in the box.

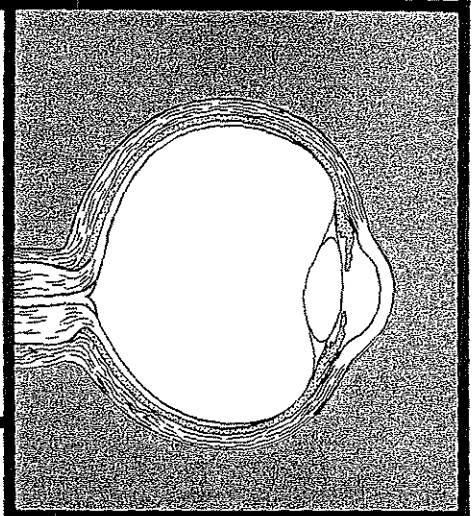
1.	___	o	___	a	___			
2.	___	o	___	v	___	x		
3.			___	o	___	c	___	v ___
4.		p	___	i	___	m		

1. _____ point (where light rays converge)
2. lens that is thicker at the center
3. lens that is thinner at the center
4. glass shaped like a wedge

HOW DO WE SEE?

21





retina: the nerve layer of the eye

rods: nerve cells that are sensitive to brightness

cones: nerve cells that are sensitive to color

AIM 21 | How do we see?

At this moment you are reading. Your eyes are open. They must be open. Otherwise, you could not see this page—or anything else.

The eyes are sense organs. They are the organs that allow us to see. The eyes receive and focus light. The light messages then go to the brain. The brain tells us what the light means. It tells us *what* we are seeing.

The eye has several transparent parts. Each part *refracts* light that enters the eye. In a normal eye, the light rays converge exactly upon the *retina* [RET nuh].

The retina is at the back part of the eye. It is made up of two kinds of nerve cells: *rods* and *cones*.

- *Rods* are sensitive to *brightness* but not to color.
- *Cones* are sensitive to *color*. Without cones, we would not see color. Everything would be seen as black and white and shades of gray.

The tissues of the retina join to form the *optic nerve*. The optic nerve leads into the brain.

Every part of the eye that refracts light has a "set" focus. Its power does not change. Every part, that is, except the lens.

The lens of the eye can change focus. It becomes stronger when we are looking at something close-up. This is important because the eye needs a stronger power for close vision. If the lens of the eye did not change focus, close-up things would seem blurry to most people.

THE EYE

Figure A shows the inside of an eye. It also shows light rays passing through. Study the figure. Then answer the questions.

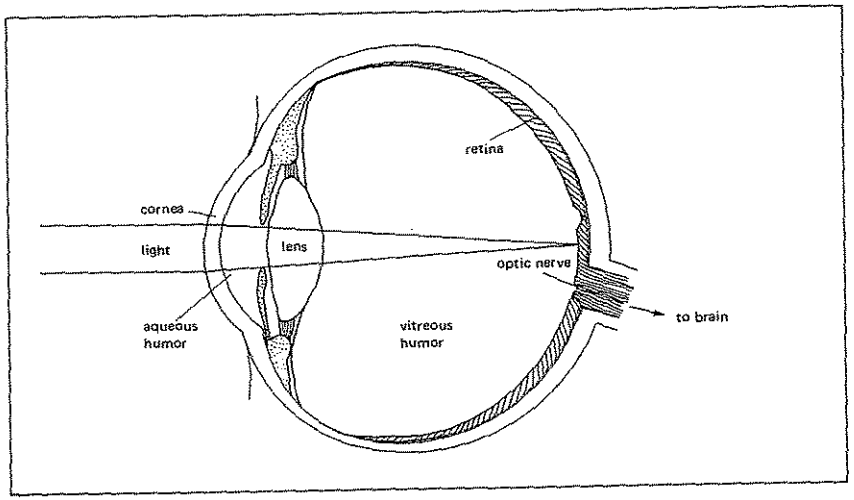


Figure A

1. The first refracting medium of the eye is sometimes called the "window of the eye." What is its name? _____
2. Directly behind the cornea is a transparent liquid. What is its name?
   _____
3. The eye has a thick double-convex tissue. What is it called?
   _____
4. Behind the lens is a transparent jelly-like material. What is its name?
   _____
5. List (in order) the refracting parts of the eye:
   _____ _____ _____
   _____
6. In a normal eye, light rays converge upon the _____.

7. The retina is made up of two kinds of nerve cells. Name them.

_____ and _____

8. Rods are sensitive to _____.

9. Cones are sensitive to _____.

10. Retina tissues join to form the _____.

11. The optic nerve leads into the _____.

12. We actually "see" with the _____.

COMPLETING SENTENCES

Complete the sentences with the choices below.

color	converge	refract
lens	eye	brightness
optic nerve	brain	transparent
retina	stronger	

1. The organ that is sensitive to light is the _____.

2. The eye has several _____ parts.

3. The transparent parts of the eye bend, or _____, light.

4. The nerve layer of the eye is called the _____.

5. In a normal eye, light rays _____ upon the retina.

6. The retina is made up of rods and cones. Rods are sensitive to _____.

   Cones are sensitive to _____.

7. Retina tissues join to form the _____.

8. The optic nerve leads into the _____.

9. The part of the eye that can change focus is the _____.

10. When we look at close-up things, the power of the lens becomes

    _____.

MATCHING

Match the [illegible] each number.

1. _____ eye	a)	first refracting part of the eye
2. _____ cornea	b)	leads to the brain
3. _____ retina	c)	made up of rods and cones
4. _____ lens of the eye	d)	organ of sight
5. _____ optic nerve	e)	can change its power

IDENTIFYING PARTS OF THE EYE

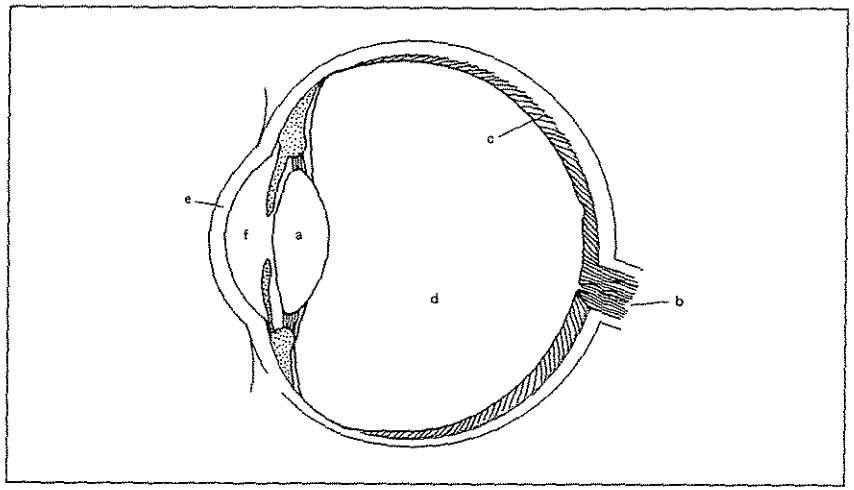


Figure B

Study Figure B. Then, identify these parts of the eye by letter.

1. optic nerve _____
2. cornea _____
3. retina _____
4. aqueous humor _____
5. lens _____
6. vitreous humor _____

REACHING OUT

Five more parts of the eye are listed below. Can you locate them by their descriptions? Write the correct names next to the numbers on Figure C.

Choroid Middle layer of the eye. Rich in blood vessels. Supplies the eye with food and oxygen.

Ciliary Muscle Tiny muscle that changes the shape and power of the lens of the eye.

Pupil Opening of the eye through which light enters.

Iris Gives an eye its color. Opens wider or narrower depending upon the amount of light present.

Sclera Tough, white outer layer of the eye.

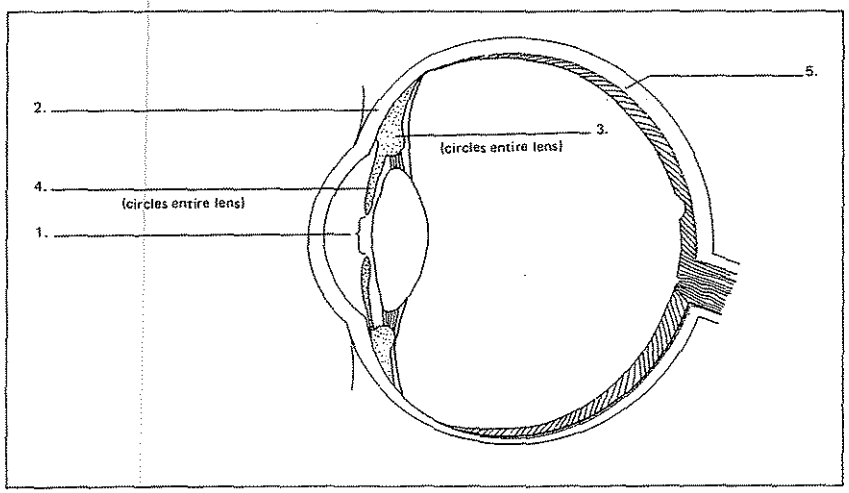
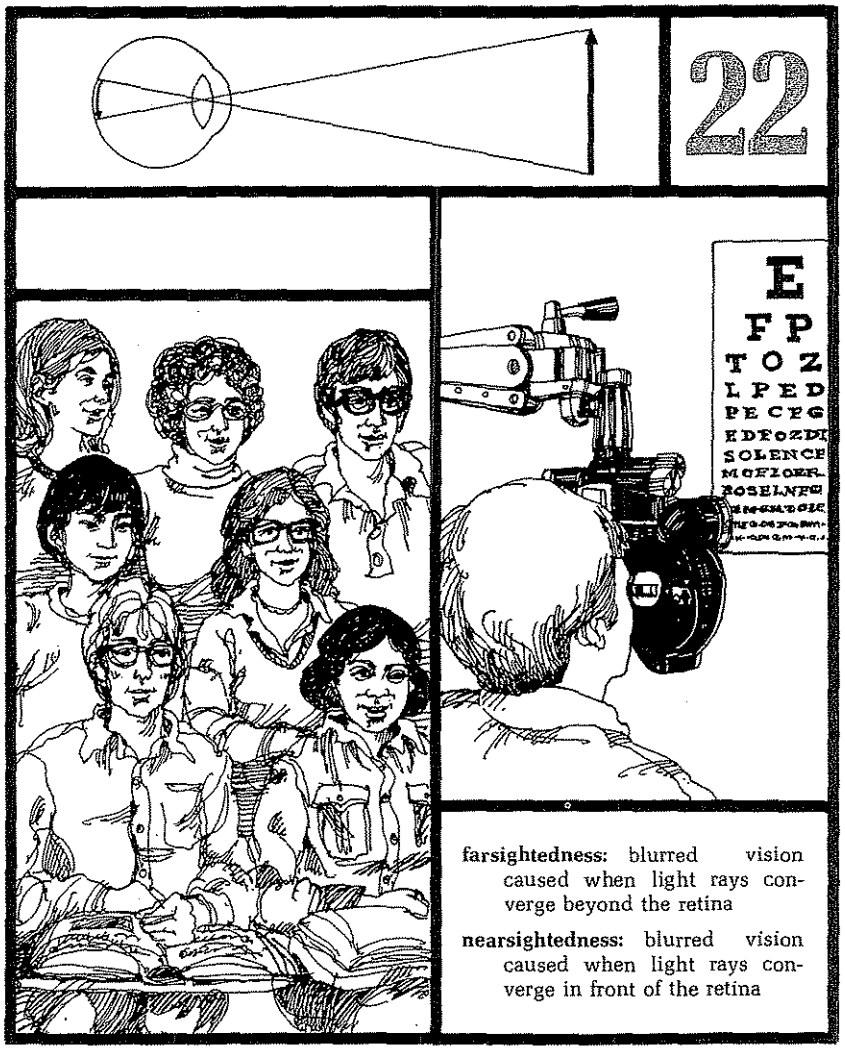


Figure C

HOW DO EYEGLASSES HELP SOME PEOPLE TO SEE BETTER?



AIM 22 How do eyeglasses help some people to see better?

How many people do you know who wear eyeglasses? Probably many. Eyeglasses are very common. In the United States alone, more than 100 million people wear them.

WHY are eyeglasses worn?

Some people do not see clearly. They have blurred vision. In most cases, eyeglasses can clear the blur.

WHAT causes blurred vision?

HOW do eyeglasses help?

Let us first see what is meant by a "normal" eye.

A "normal" eye sees clearly. Its length — that is, the distance from the cornea to the retina — is "just right." Light rays that enter a normal eye converge (come together) directly upon the retina. The image, therefore, is in perfect focus. No correcting lens is needed.

In some eyes, however, the length of the eyeball is not right. It is either a bit too long or a bit too short. Because of this, light rays do not converge on the retina. The image is out of focus. Vision is blurred.

There are two main types of blurred vision: *nearsightedness* and *farsightedness*. Both may be corrected with lenses. The lenses bend or refract the light rays so that they converge on the retina.

NEARSIGHTEDNESS

CAUSE ▪ A nearsighted eye is slightly *longer* than normal. Light rays converge at a point in *front* of the retina.

CORRECTION ▪ Nearsightedness may be corrected with a *concave* lens.

FARSIGHTEDNESS

CAUSE ▪ A farsighted eye is slightly *shorter* than normal. Light rays converge at a point *beyond* the retina.

CORRECTION ▪ Farsightedness may be corrected with a *convex* lens.

TYPES OF LENSES

Study Figure A. Then answer the questions.

1. Which lens is *concave*? _____ (a, b)
2. Which lens is *convex*? _____ (a, b)
3. A convex lens makes light rays _____ (come together, spread apart).
4. A concave lens makes light rays _____ (come together, spread apart).

Remember these facts. You will need to know them for the next exercises.

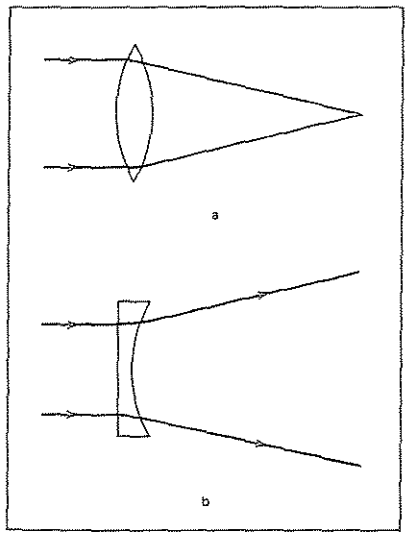


Figure A

TYPES OF VISION

Figures B through D show three types of vision. Study the figures. Then answer the questions with each.

1. "Eyeball length" means the distance between the _____ and _____.

Look at Figure B.

2. a) Is a normal eye too long? _____
   b) Is a normal eye too short? _____
3. In a normal eye, light rays converge _____ (directly on, in front of, beyond) the retina.
4. The image on the retina is _____ (in focus, out of focus).
5. Vision is _____ (blurred, clear).

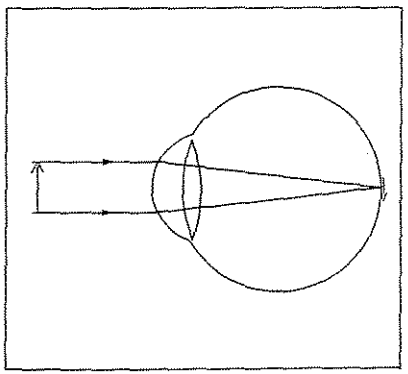


Figure B *THE NORMAL EYE*

6. Compare the eye in Figure C to the normal eye. A nearsighted eye is _____ than a normal eye.
(longer, shorter)

7. Light rays converge _____ (directly upon,) _____ (in front of, beyond) the retina.

8. The image on the retina is _____ (in, out of) focus.

9. Vision is _____ (blurred, clear).

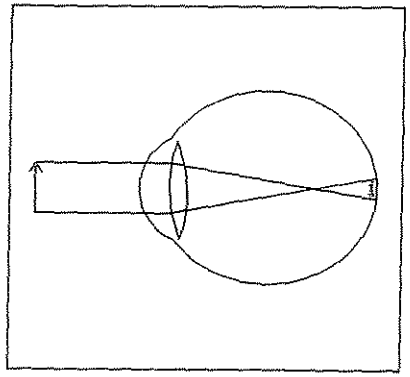


Figure C *THE NEARSIGHTED EYE*

10. a) To clear the blur, we must make the light rays fall directly upon the retina. The rays must be made _____ (longer, shorter).

b) What kind of lens does this? _____ (concave, convex)

11. What kind of lens can correct nearsightedness? _____ (concave, convex)

12. Compare the eye in Figure D to the normal eye. A farsighted eye is _____ (longer, shorter) than a normal eye.

13. Light rays converge _____ (directly on, in front of, beyond) the retina.

14. The image on the retina is _____ (in, out of) focus.

15. Vision is _____ (blurred, clear).

16. To clear the blur, we must make the light rays fall directly upon the retina. The rays must be made _____ (longer, shorter).

17. What kind of lens does this? _____ (concave, convex)

18. What kind of lens can correct farsightedness? _____

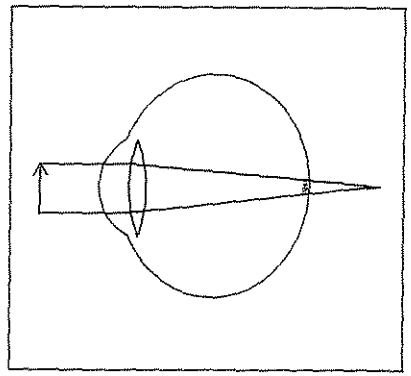


Figure D *THE FARSIGHTED EYE*

FILL IN THE CHART

Several characteristics are listed on the chart. Each one is a characteristic of *a normal eye*, or *a nearsighted eye*, or *a farsighted eye*. Decide which each is a characteristic of. Check the correct box. (Three of these may be checked in two boxes.)

		Normal Eye	Nearsighted Eye	Farsighted Eye
1.	eyeball too long			
2.	vision blurred			
3.	may be corrected with convex lenses			
4.	light rays converge beyond the retina			
5.	may be corrected with concave lenses			
6.	lens correction needed			
7.	eyeball too short			
8.	vision perfectly clear			
9.	image on retina out of focus			
10.	light rays converge in front of retina			
11.	image on retina in focus			
12.	light rays converge upon the retina			
13.	no lens correction needed			

Figure E

The eye converges light. However, stronger converging power is needed for close vision than for far vision.

The *ciliary* [SILL ee er ee] *muscle* controls the shape and power of the lens. The lens becomes stronger when we are looking at close-up things.

The ciliary muscle stays flexible and does its job well— up to the age of about 40 years. After this age, it becomes sluggish. Because of this, the lens does not change its power as much as is needed. Outside help in the form of eyeglasses may be needed.

The person in Figure E is over 40 years old. She does *not* need eyeglasses for far vision. But she *does* need "reading glasses."

What kind of lens would be used in her reading glasses, convex or concave?

_____

WORD SEARCH

The words in this list are hidden within the group of letters in the box. Try to find each word. When you find it, draw a line around the word. The spelling may go in any direction.

RODS
CONES
CONVERGE
FOCUS
RETINA
CORNEA
LENS
OPTIC
VISION

E	G	R	E	V	N	O	C	F
R	Y	E	C	O	N	O	O	S
O	P	T	I	C	R	C	N	E
D	N	I	E	N	U	E	E	S
S	R	N	E	S	L	A	S	I
C	O	A	V	I	S	I	O	N

WHAT IS THE VISIBLE SPECTRUM?

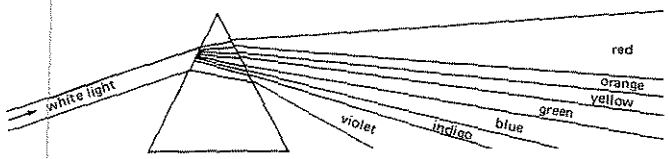
AIM 23 What is the visible spectrum?

Nature puts on many beautiful "shows." One of the most beautiful is the *rainbow*. A rainbow frames the sky with an arc of colors.

Have you ever seen a rainbow? It was probably right after a rainstorm. Let's find out what causes a rainbow to form.

The sun gives off "white" light. White light seems to have no color at all. But this is not true. Just the *opposite* is true. White light is made up of "every color of the rainbow."

This interesting fact was discovered in 1666. In that year, Sir Isaac Newton, an English scientist, was experimenting with light. He passed white light through a glass prism. The prism broke up the white light. A rainbow of colors was produced: *red, orange, yellow, green, blue, indigo* [IN duh go], and *violet*.



These colors are called the *visible spectrum*. The order of the colors never changes.

How does this explain a rainbow? During a rainstorm, there are billions of tiny drops of water in the air. Sometimes they act like prisms. They break up sunlight into its spectrum of colors. This produces a rainbow.

When you studied sound, you learned that pitch depends upon frequency of vibration. Frequency tells us how fast sound energy vibrates. Color depends upon frequency of vibration, too.

All colors vibrate very fast—*much, much* faster than sound. But each color vibrates at a different speed (and wavelength). Different vibration speeds produce different colors. The slowest vibration produces red. The speed increases as you go from red to violet.

UNDERSTANDING THE VISIBLE SPECTRUM

Study Figure A. Then answer the questions.

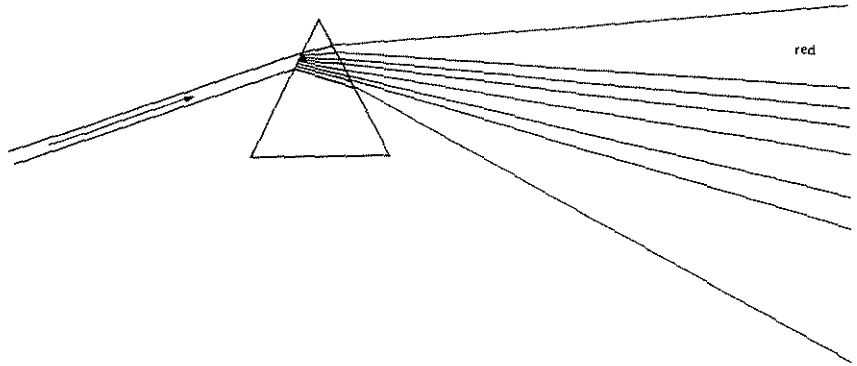


Figure A

1. Light is passing through a glass shaped like a triangle. What do we call this kind of glass? _____
2. What kind of light is entering the prism? _____
3. The prism is _____ (reflecting, refracting) the light.
4. The white light is breaking up. It is separating into a rainbow of colors. What do we call this rainbow of colors? _____
5. There is an easy way to remember the colors of the visible spectrum. Just think of the name **ROY G. BIV**. The R stands for red. Red is the first color of the visible spectrum. It is labeled in Figure A. Now use **ROY G. BIV** to label the rest of the colors in Figure A.
6. Which color vibrates the fastest? _____
7. Which color vibrates the slowest? _____
8. Which color is refracted the most? _____
9. Which color is refracted the *least*? _____

COMPLETING SENTENCES

Complete the sentences with the choices below. Two of these may be used twice.

visible spectrum	blue	no
violet	red	yellow
many	much faster	how fast
orange	green	indigo
Sir Isaac Newton	prism	

1. Light from the sun gives off light that seems to have _____ color.
2. "White" light is really made up of _____ colors.
3. The colors that make up white light are called the _____.
4. The colors of the visible spectrum in order are _____

   _____ _____ _____

   _____ _____ _____.
5. Color depends upon _____ light energy vibrates.
6. The color that vibrates the *fastest* is _____.
7. The color that vibrates the *slowest* is _____.
8. Light energy vibrates _____ than sound energy.
9. We can separate the colors of white light with a _____.
10. The scientist who discovered that colors make up white light was named _____.

REACHING OUT

In Figure B, light is passing through *two* prisms. They are facing in opposite directions.

1. What kind of light do you think is coming out of the prism on the right? _____
2. What does this prove? _____

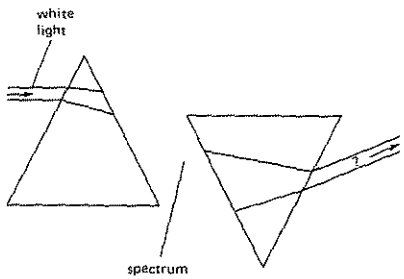
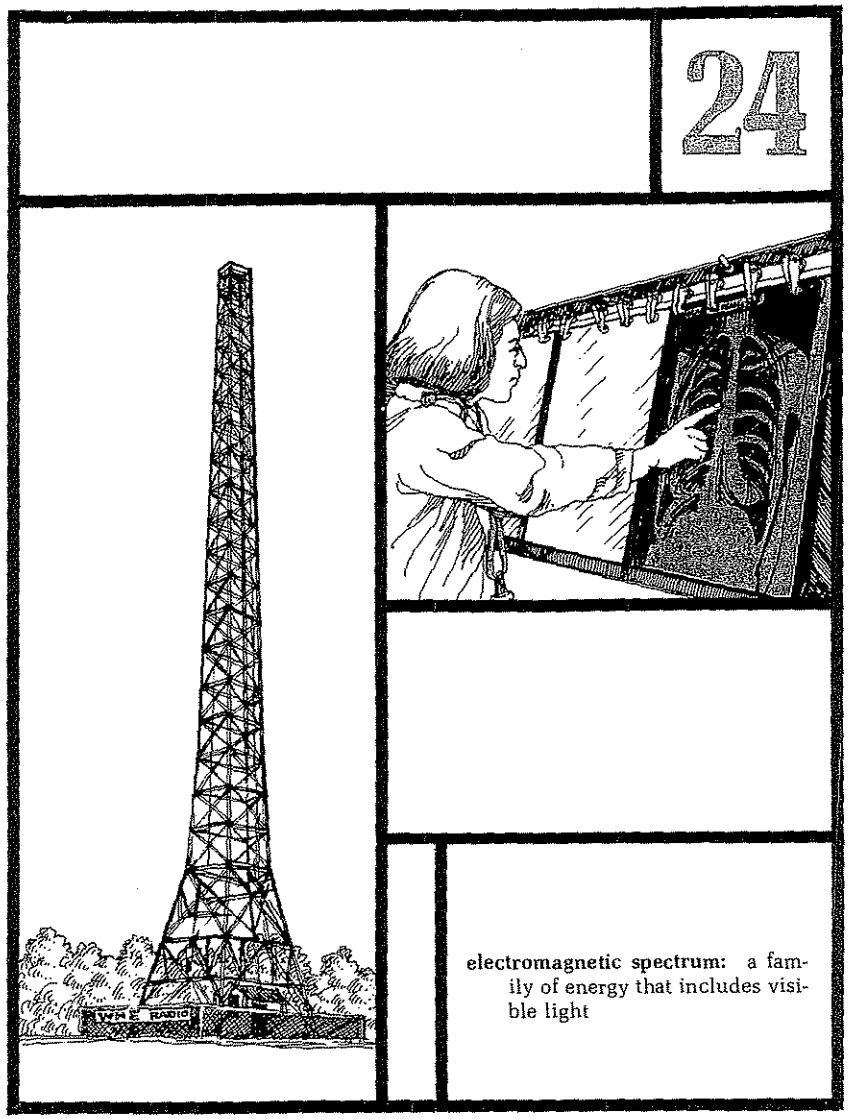


Figure B

WHAT IS INVISIBLE LIGHT?



electromagnetic spectrum: a family of energy that includes visible light

AIM 24 What is invisible light?

The visible spectrum is a member of an even larger spectrum. It is called the *electromagnetic* (i LEK troh mag NET ik) *spectrum*.

THE ELECTROMAGNETIC SPECTRUM IS A SERIES OF RAYS (OR WAVES). This series of rays ranges from rays that vibrate very slowly to rays that vibrate very fast. See Figure A on the facing page. For example, the band of radio waves vibrate slowly. At the other end of the spectrum are the band of cosmic rays, which vibrate very fast.

In Aim 4 you learned about wavelengths. And in Aim 6 you learned about frequency, or how fast a wave vibrates. Each kind of electromagnetic wave (ray) has a different frequency and wavelength. Slow-frequency waves have long wavelengths. Fast-frequency waves have short wavelengths. ALL WAVES TRAVEL AT THE SAME SPEED — THE SPEED OF LIGHT.

Our eyes are sensitive to a small band of electromagnetic waves. We call this band of waves VISIBLE LIGHT. We see objects because they give off or reflect visible light rays.

Our eyes are not sensitive to infrared rays or to ultraviolet rays. However, there is photographic film that is sensitive to infrared rays. Such film makes pictures of objects based on the infrared rays they send out. These pictures can be made in complete darkness.

Infrared rays from the sun or any hot object are felt as heat. If an object absorbs them, the object is warmed. However, glass transmits infrared rays and so is not warmed by them.

Ultraviolet rays are the rays that give us a sunburn. A small amount of ultraviolet energy is healthful to most plants and animals. Too much is harmful.

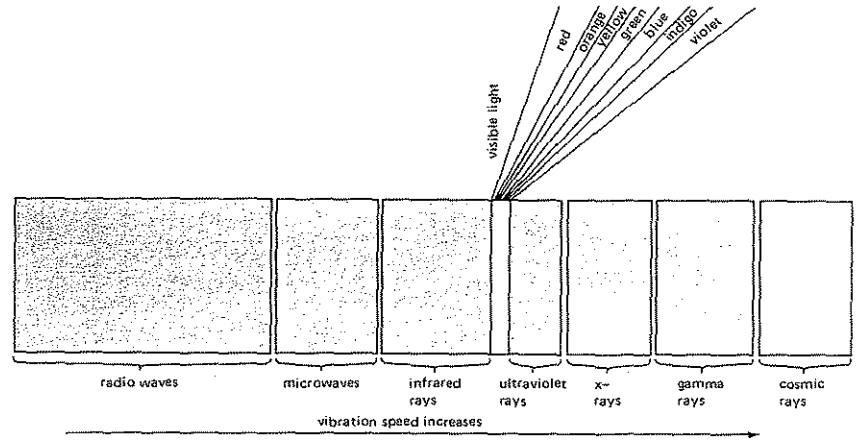


Figure A

1. List the members of the electromagnetic spectrum from left to right.

   _____ _____ _____ _____

   _____ _____ _____ _____

2. a) The members of the electromagnetic spectrum vibrate

   _____.
   at one speed. at different speeds

   b) The kind of energy depends upon how _____ the waves

   _____.

3. The farther to the right you go on the electromagnetic spectrum, the

   _____ the waves vibrate.
   faster. slower

4. Which vibrate faster,

   a) gamma rays or radio waves? _____

   b) gamma rays or cosmic rays? _____

   c) ultraviolet rays or x-rays? _____

   d) infrared rays or ultraviolet rays? _____

   e) visible light or radio waves? _____

5. Which is the only form of energy that we can see? _____

6. List the members of the visible spectrum in order, starting with red. _____

_____

7. a) Ultraviolet is to the _____ of violet.
   right, left

   b) Violet _____ be seen. But ultraviolet _____ be seen.
   can, cannot can, cannot

   c) Ultraviolet cannot be seen because it vibrates too _____.
   slowly, rapidly

8. a) Infrared is to the _____ of red.
   right, left

   b) Red _____ be seen. But infrared _____ be seen.
   can, cannot can, cannot

   c) Infrared cannot be seen because it vibrates too _____.
   slowly, quickly

9. Ultraviolet and infrared are called _____ light.

TRUE OR FALSE

Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. _____ Visible light is part of the electromagnetic spectrum.
2. _____ Visible light takes up only a small part of the electromagnetic spectrum.
3. _____ Every member of the electromagnetic spectrum vibrates at the same speed.
4. _____ We can see every member of the electromagnetic spectrum.
5. _____ We can see ultraviolet light.
6. _____ We can see infrared light.
7. _____ Ultraviolet light vibrates too quickly for us to see it.
8. _____ Infrared light vibrates too quickly for us to see it.
9. _____ Infrared rays are heat rays.
10. _____ The sun gives off ultraviolet and infrared energy.

THE ELECTROMAGNETIC SPECTRUM AND ITS USES

Different parts of the electromagnetic spectrum have been put to different uses. Here are some important uses.

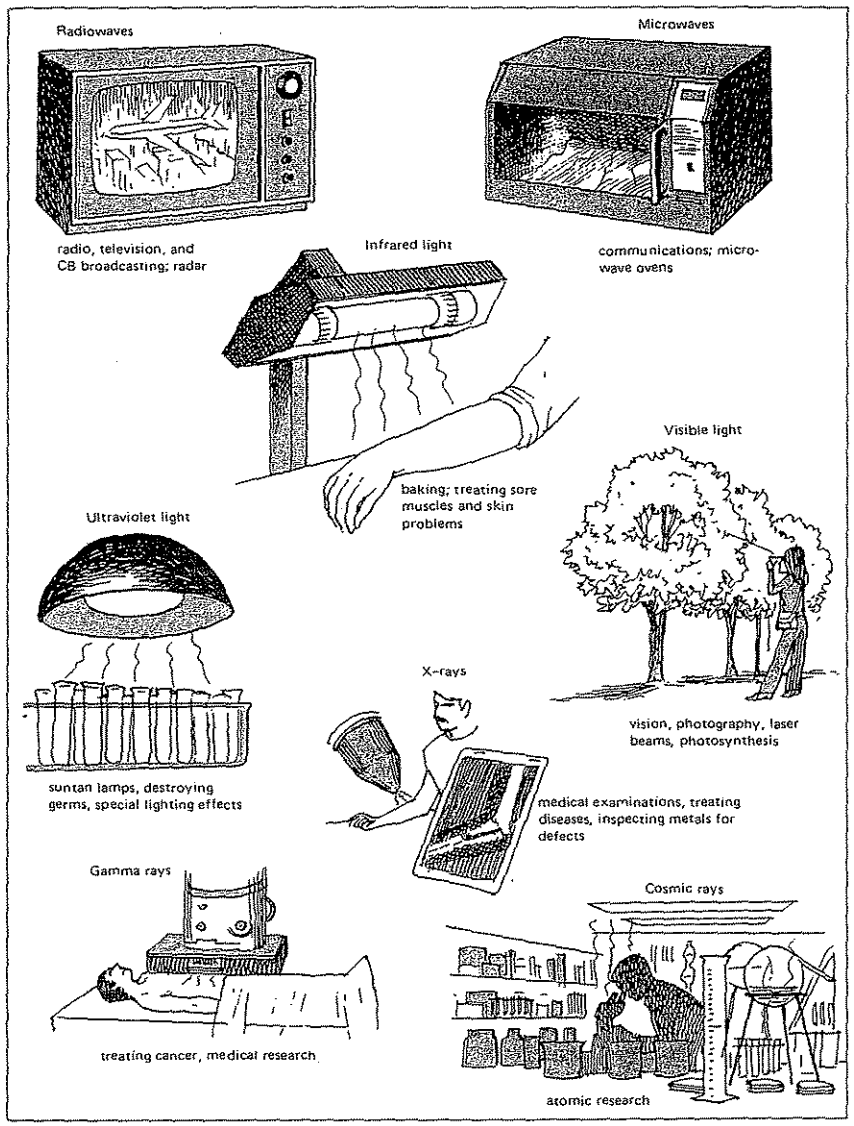
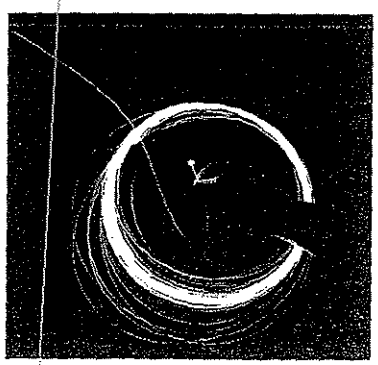
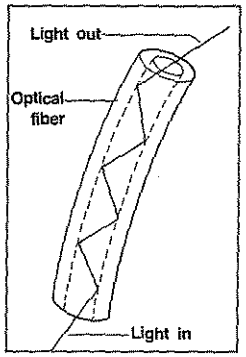


Figure B

KEEPING UP WITH SCIENCE





LIGHT CONVERSATION

Your telephone rings. You wonder, "Is it for me? Who is calling? A friend close by? A relative thousands of miles away?" You lift the receiver and quickly find out. You talk, and you listen. So does the person on the other end. That is what the telephone is all about—conversation—talking and listening.

Telephone commmunication depends upon several energy changes. When you talk, the sound energy of your voice is changed to *electricial energy*. The receiver changes the electricial energy back to sound energy.

Optical fibers can also carry telephone conversations. Instead of metal wires carrying electricial signals, optical fibers carry light signals to your phone. These signals will then be changed to sound.

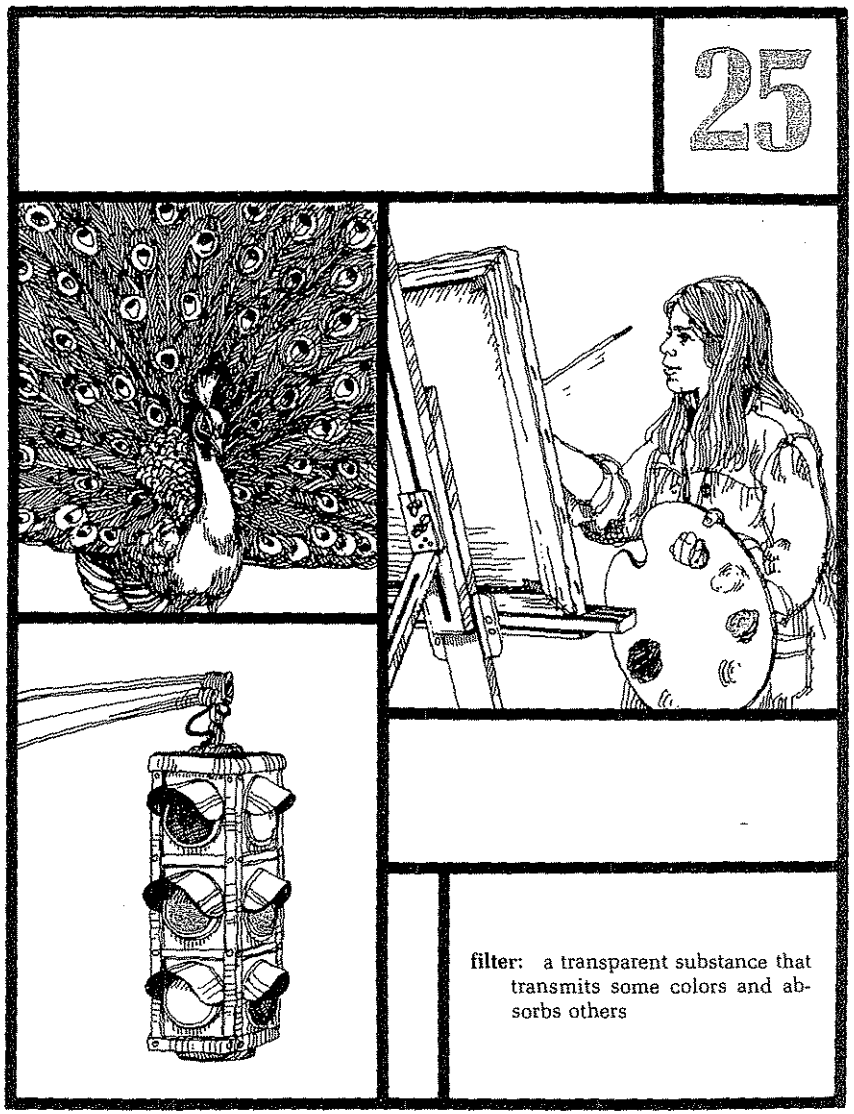
You have heard of cable television. Electricial signals are fed into your TV through a *wire* cable. In the future, optical fibers will carry light signals from the TV station to your home.

What are optical fibers? Optical fibers are very thin glass rods. They are about as thin as a human hair. Optical fibers are very practical. They are lighter, less bulky, and much less expensive than metal wire. They can also carry many more telephone conversations and TV programs than metal wire can.

How does light move along an optical fiber? Light, you know, travels only in a straight line. Light does not curve or bend. An optical fiber can never be perfectly straight—it doesn't have to be. The inside walls of optical fibers reflect light over and over again along its entire length. As a result, the light within an optical fiber follows any path the fiber takes. Light that enters one end of a fiber always leaves at the opposite end—never along its sides.

Optical fibers are also used to light up hard-to-get-at places. Fiber rods are inserted into organs like the food pipe, windpipe, and parts of the lungs, stomach, and bladder. An eyepiece allows the doctor to see the area. A camera can be attached to the eyepiece to take pictures.

WHAT GIVES THE OBJECT ITS COLOR?



AIM 25 What gives an object its color?

Joan's dress is red. Tom is wearing a *blue* shirt. Grass is green. An orange is of course . . . *orange*. Color, color, everywhere! Look around. How many colors do you see?

You have learned that when light strikes an object one of three things can happen. The light can be *reflected*, *absorbed*, or *transmitted*. What happens to the light when it strikes an object is what causes the color we see.

What causes color in opaque and transparent objects?

OPAQUE OBJECTS The color of an opaque object is the color that it *reflects*. For example, a red object reflects only *red* light. It absorbs all other colors. A green object reflects only *green* light. It absorbs all other colors.

What about white and black objects? A white object reflects *all* the colors that make up white light (ROY G. BIV). A black object, on the other hand, *absorbs* all the colors that strike it. No color is reflected. Black is an *absence* of color.

Most objects reflect more than one color. The colors combine. We see them as *mixtures* of colors, like blue-green and red-orange.

TRANSPARENT OBJECTS The color of a transparent (or translucent) object is the color that *passes through* the object. For example, red glass transmits only *red* light. It absorbs all other colors. Blue glass transmits only *blue* light. It absorbs all other colors.

Ordinary window glass transmits all colors. White light that has passed through window glass is still white light. It still has all the colors of white light. None of the colors has been absorbed by the glass.

You have learned that some substances transmit only some colors. All other colors are blocked. These substances are called *filters*. Filters are often used in spotlights and in photography.

OBJECTS AND THEIR COLORS

Study Figures A through E. Answer the questions with each.

OPAQUE OBJECTS

1. a) List the colors that are *striking* the object in Figure A. _____

   b) Together, these colors make up what kind of light? _____

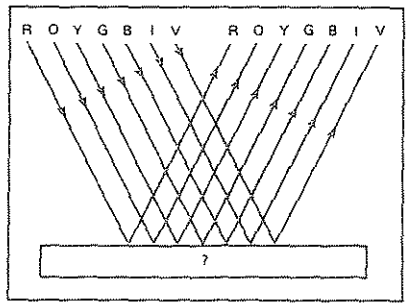


Figure A

2. a) List the colors that are being *reflected*. _____

   b) Together, these colors make up what kind of light? _____

3. The color of an opaque object is the color that the object _____. (reflects, absorbs, transmits)

4. a) What color is the object in Figure A? _____

   b) How do you know? _____

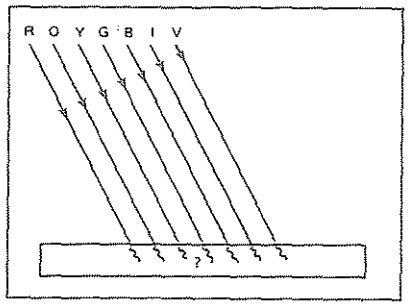


Figure B

5. List the colors that are striking the object in Figure B. _____

6. a) All the colors are being _____. (reflected, absorbed)

   b) None of the colors is being _____. (reflected, absorbed)

7. The color of an opaque object is the color that the object _____. (reflects, absorbs, transmits)

8. a) What color is the object in Figure B? _____

   b) How do you know? _____

9. List the colors that are striking the object in Figure C. _____

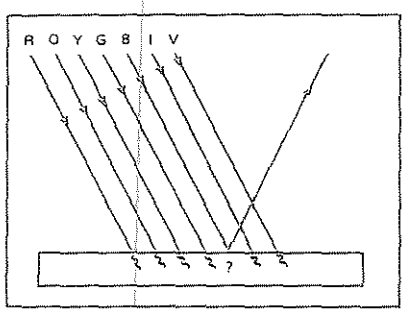


Figure C

10. List the colors that are being absorbed. _____

11. Which color is being reflected? _____

12. What gives an opaque object its color? _____

13. a) What is the color of the object in Figure C? _____

b) Why? _____

TRANSPARENT OBJECTS

14. List the colors that are striking the glass in Figure D. _____

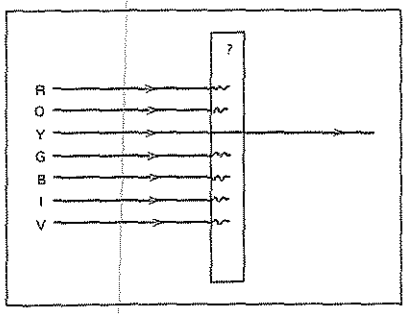


Figure D

15. a) Which of these colors are being absorbed? _____

b) Which color is being transmitted? _____

16. The color of a transparent object is the color it _____.
reflects, absorbs, transmits

17. a) What is the color of the glass in Figure D? _____

b) Why? _____

18. What is the definition of a filter? _____

19. a) Is this glass a filter? _____

b) Why? _____

White light is striking the glass in Figure E.

20. List the colors of white light. _____

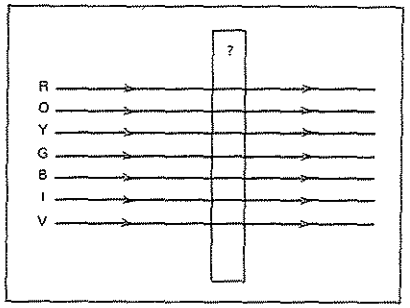


Figure E

21. a) Are any of these colors being absorbed? _____

b) All the colors are being _____.
reflected, transmitted

22. What kind of light is leaving the glass? _____

23. a) Is this glass a filter? _____

b) Why? _____

24. Does this glass have a color? _____

25. a) What kind of glass is this? _____

b) Where can it be found? _____

REACHING OUT

The colors of the American flag are red, white, and blue.

What color or colors does each of these colors reflect?

1. Red _____
2. White _____
3. Blue _____

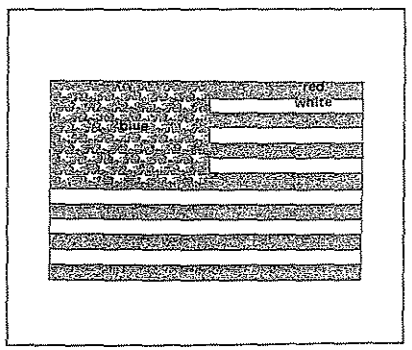


Figure F

COMPLETING SENTENCES

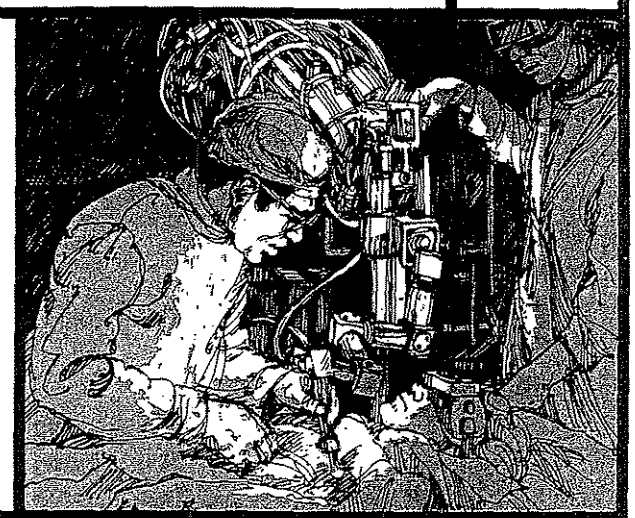
Complete the sentences with the choices below. Two of these may be used twice.

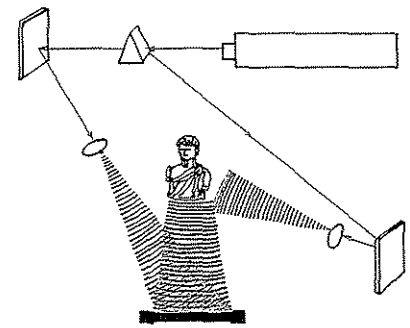
green	all	transparent
filter	red	does not
absorbs	opaque	transmits
reflects		

1. An object that does *not* allow light to pass through it is said to be _____.
2. An object that *does* allow light to pass through it is said to be _____.
3. The color of an opaque object is the color it _____.
4. A white object reflects _____ the colors that make up white light.
5. A black object _____ reflect light. A black object _____ all the light that strikes it.
6. A green sweater absorbs all colors except _____.
7. The color of a transparent object is the color it _____.
8. Window glass transmits _____ the colors that strike it.
9. A red glass transmits only the color _____. It _____ all other colors.
10. A substance that transmits some colors and blocks others is called a _____.

WHAT IS LASER LIGHT?

26





laser: very strong, concentrated, single-color light

AIM 26 | What is laser light?

Light is a form of energy. Light can make things move. It can do work for us.

In Aim 23 you learned that a mixture of all the colors produces white. Sunlight is called white light. It is a mixture of visible light waves that have many wavelengths. These are the waves that our eyes see as colors.

Waves have energy. However, the energy of a mixture of different waves cancels each other out. You learned in Aim 11 that sound waves of different wavelengths can cancel each other out.

Single-color light has just one wavelength. It can have more energy than mixed light.

We can produce single-color light by using filters. But filters reduce the *amount* of light. Very little light energy is left. And what is left spreads out—just like white light does.

Scientists use electronics to produce single-color light. But it is more than just "single color." This light has very special properties.

- This light is very concentrated.
- All the waves are in *phase* *. They work together.
- The waves stay together. They hardly spread out at all.

This produces an enormous amount of light (and heat) energy. We call this light *laser* light.

Laser light has many uses, but it is very diffucult to handle. Much research is being done to put the laser to work. There has been some success. Laser energy is used in medicine, industry, and scientific research. It is also used by the military for national defense.

Some present-day and future uses of laser energy are shown on the following pages.

*Light waves may be in phase or out of phase, just like the sound waves you learned about in Aim 11.

COMPARING WHITE LIGHT AND LASER LIGHT

Figure A shows white light. Figure B shows a beam of laser light. Look at the figures. Then answer the questions.

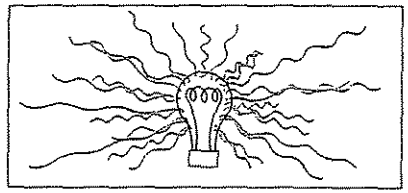


Figure A

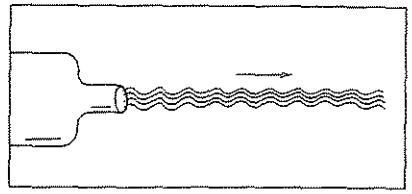


Figure B

1. White light is made up of _____. (one color, a mixture of colors)
2. Laser light is made up of _____. (one color, a mixture of colors)
3. Every color has _____ wavelength. (the same, a different)
4. Laser light waves have _____. (one wavelength, many wavelengths)
5. Waves of white light are mostly _____. (in phase, out of phase)
6. All laser waves are _____. (in phase, out of phase)
7. Out-of-phase waves make energy _____. (stronger, weaker)
8. In-phase waves make energy _____. (weaker, stronger)
9. The waves of white light _____ combine their energy. (do, do not)
10. Laser waves _____ combine their energy. (do, do not)
11. The waves of white light _____. (spread out, hardly spread out)
12. Laser waves _____. (spread out, hardly spread out)
13. White light _____ concentrated energy. (is, is not)
14. Laser light _____ concentrated energy. (is, is not)

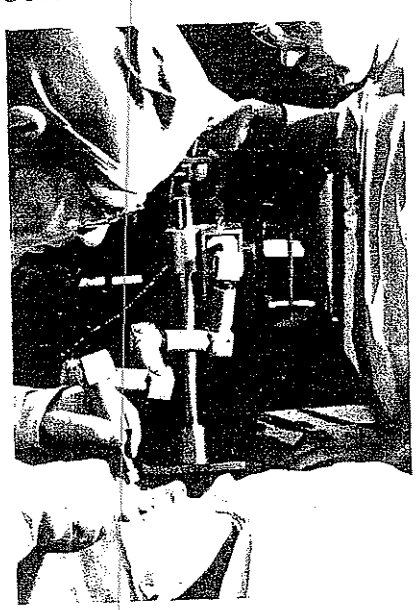


Figure C

PRESENT: Lasers are used in delicate eye surgery. They can repair detached (split) retinas.

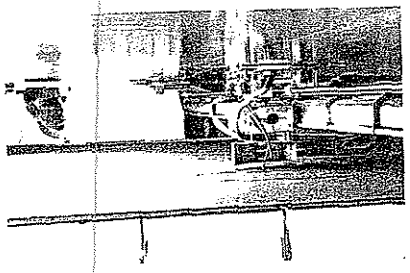


Figure E

PRESENT: Lasers control machine tools with extreme accuracy.

Lasers are even used to control the cutting of cloth as in Figure E.

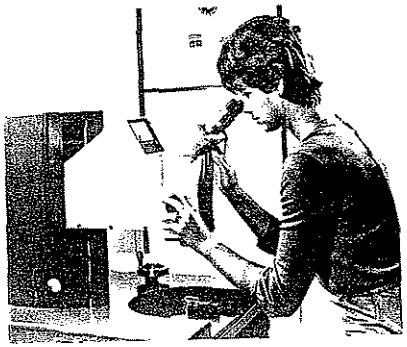


Figure D

PRESENT: Lasers are used for drilling and welding ultra-thin holes. A microscope is needed to do these delicate jobs.

Figure F

FUTURE: A single narrow laser beam can carry many radio and television channels.

Laser energy can also carry telephone messages. In theory, one laser system can carry 80 million conversations. This is nearly four for every person in the United States.

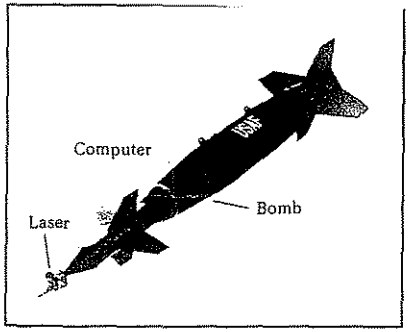


Figure G

PRESENT: Laser beams very accurately guide bombs and missiles to targets.

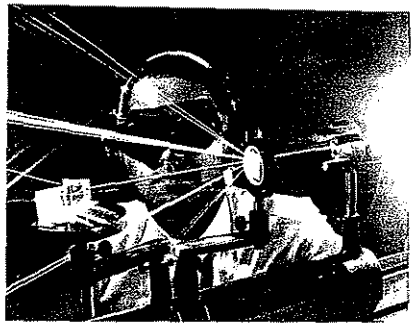


Figure H

PRESENT: Scientists use lasers to "look" inside molecules.

Lasers are used in cancer research. They are even used to predict earthquakes.

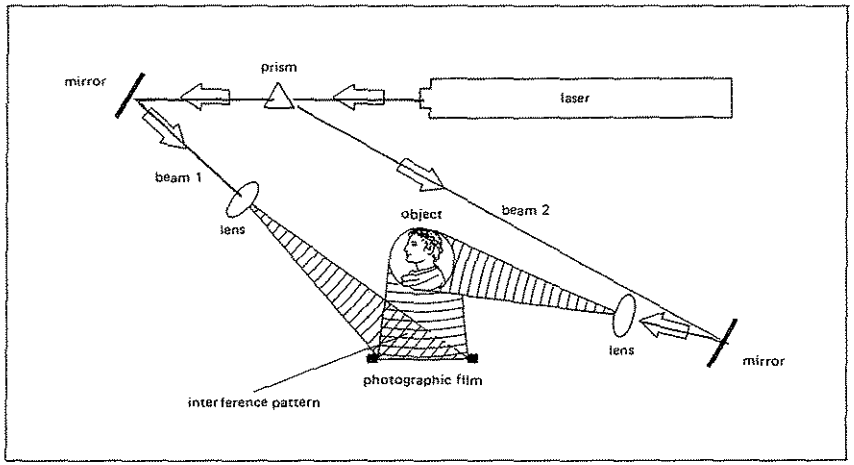


Figure I

PRESENT: One of the most exciting uses of laser energy is in *holography* [huh LOG ruh fee]. In holography, laser beams are used to project a picture of an object. The picture (image) is called a *hologram*. A hologram looks so real that it is hard to believe. It looks three-dimensional. A hologram can make an object look as if it is suspended in mid-air. The image shows full roundness and depth. And you can see what is lying *behind* the object simply by moving your head.

FUTURE: Holography may give us 3-D color movies and TV someday.

TRUE OR FALSE

Write T on the line next to the number if the sentence is true. Write F if the sentence is false.

1. _____ Ordinary light is made up of one color.
2. _____ Ordinary light has many wavelengths.
3. _____ The waves of ordinary light are mostly in phase.
4. _____ Laser light is made up of one color.
5. _____ Laser light has only one wavelength.
6. _____ Laser waves are all in phase.
7. _____ Ordinary light spreads out.
8. _____ Laser light spreads out a great deal.
9. _____ White light produces very strong energy.
10. _____ Laser light produces very weak energy.

REACHING OUT

The word LASER is made of the first letters of five words. These words describe how a laser is produced. What are these words? (*Hint:* You may want to do some research.)

L _____ A _____ S _____ E _____ R _____